

(10) **Patent No.:** US 9,048,147 B2
(45) **Date of Patent:** Jun. 2, 2015

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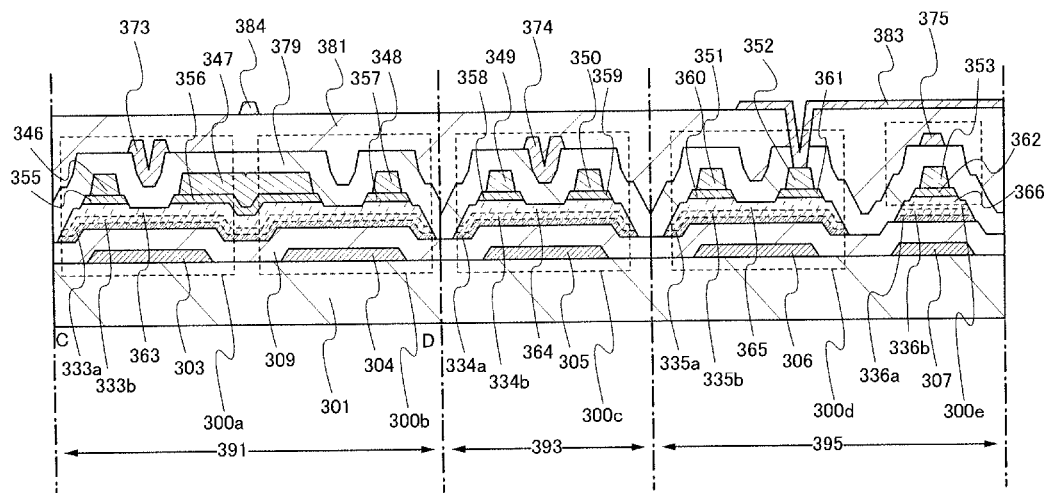
(57) **ABSTRACT**

A display device of which frame can be narrowed and of which display characteristics are excellent is provided. In a display device including a switch portion or a buffer portion, a logic circuit portion, and a pixel portion, the pixel portion includes a first inverted staggered TFT and a pixel electrode which is connected to a wiring of the first inverted staggered TFT, the switch portion or the buffer portion includes a second inverted staggered TFT in which a first insulating layer, a semiconductor layer, and a second insulating layer are interposed between a first gate electrode and a second gate electrode, the logic circuit portion includes an inverter circuit including a third inverted staggered thin film transistor and a fourth inverted staggered thin film transistor, and the first to the fourth inverted staggered thin film transistors have the same polarity. The inverter circuit may be an EDMOS circuit.

33 Claims, 29 Drawing Sheets

(52) **U.S. Cl.**
CPC ***H01L 27/1251*** (2013.01); ***H01L 29/04***
(2013.01); ***H01L 27/1214*** (2013.01); ***H01L***
29/78648 (2013.01)

(58) **Field of Classification Search**
USPC 345/92, 44, 87, 55, 204, 214
See application file for complete search history.



(56)

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FIG. 1A

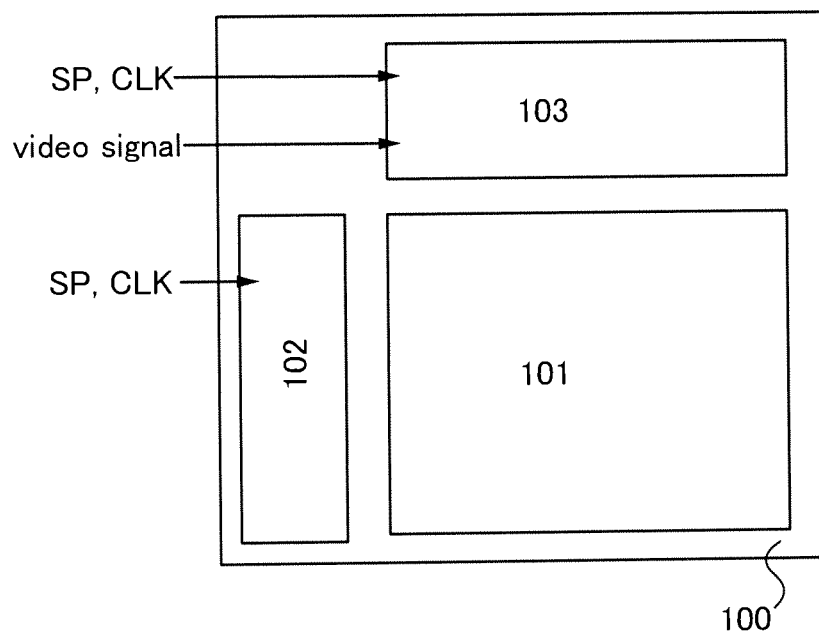


FIG. 1B

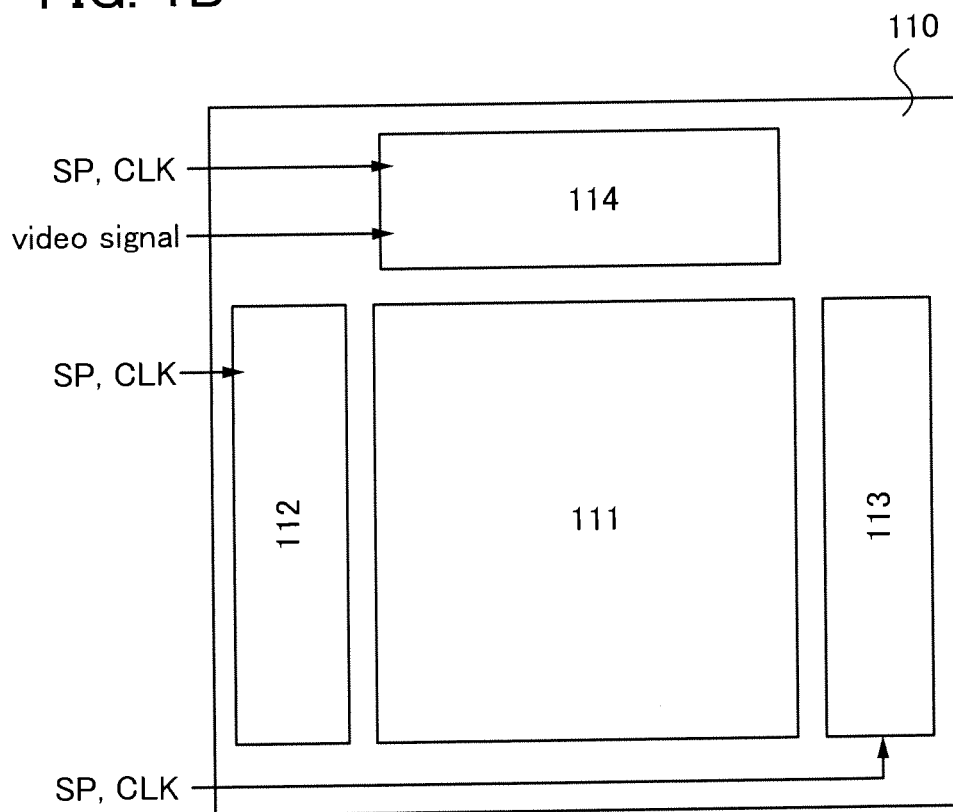


FIG. 2

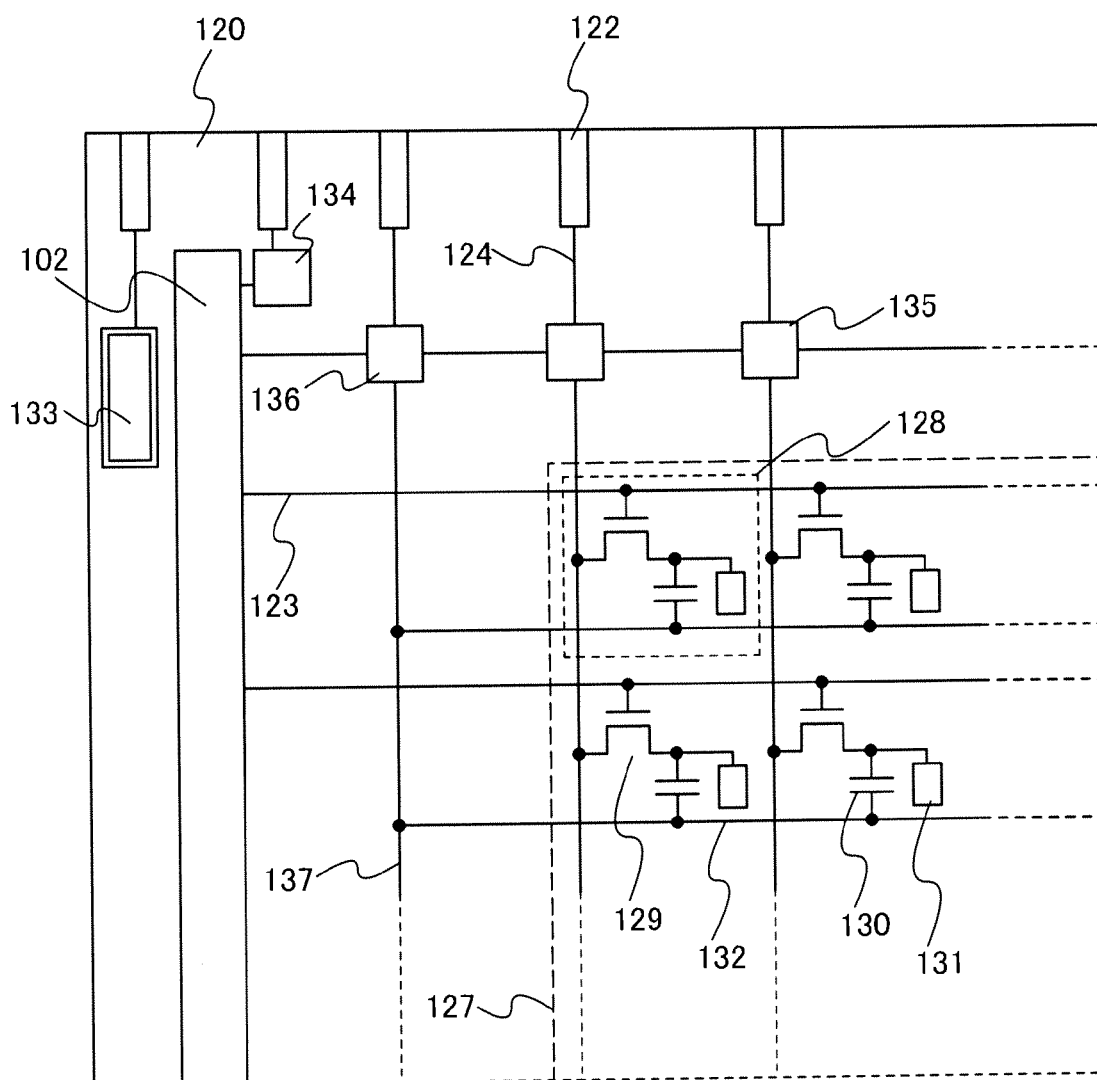
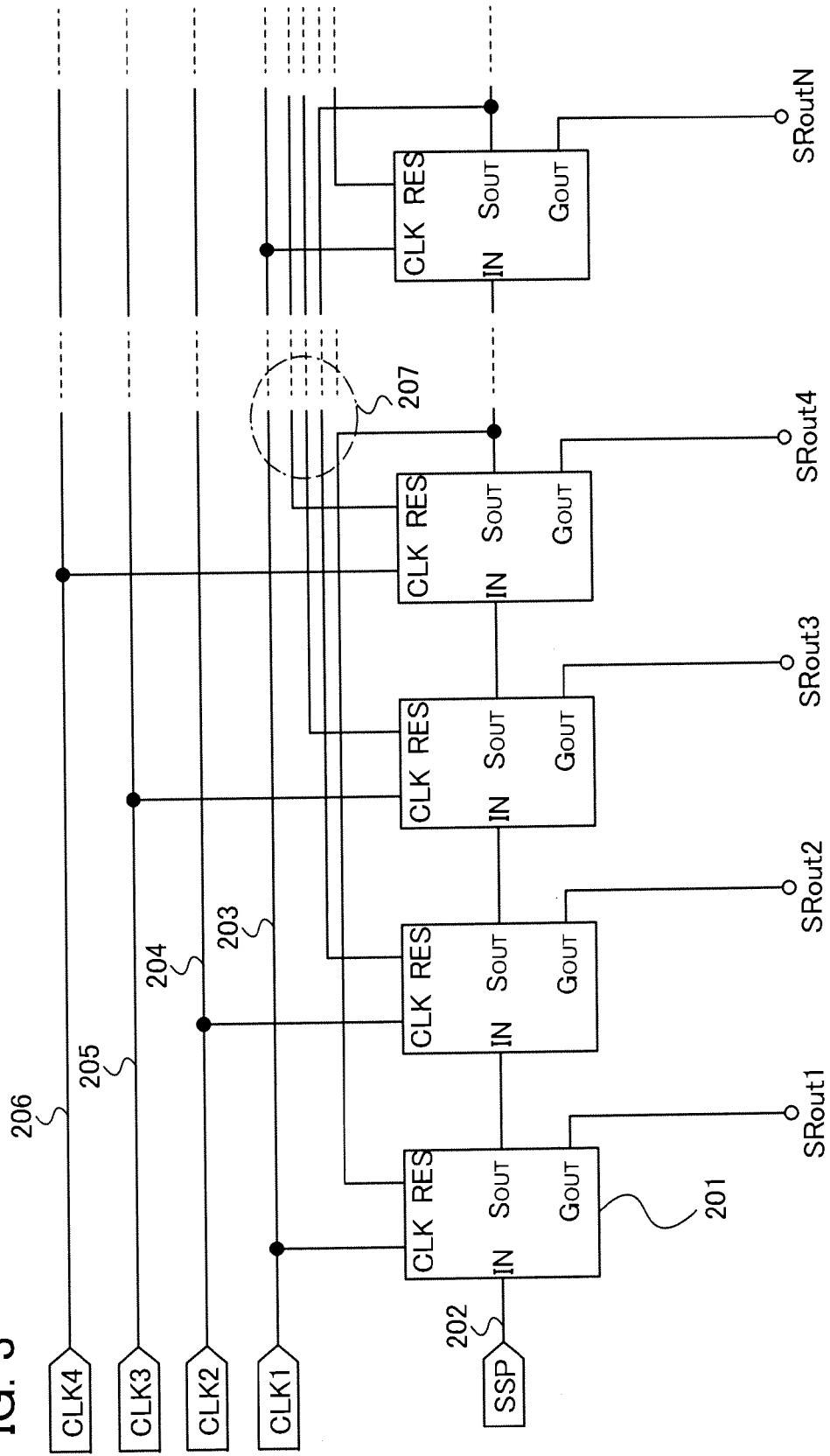


FIG. 3



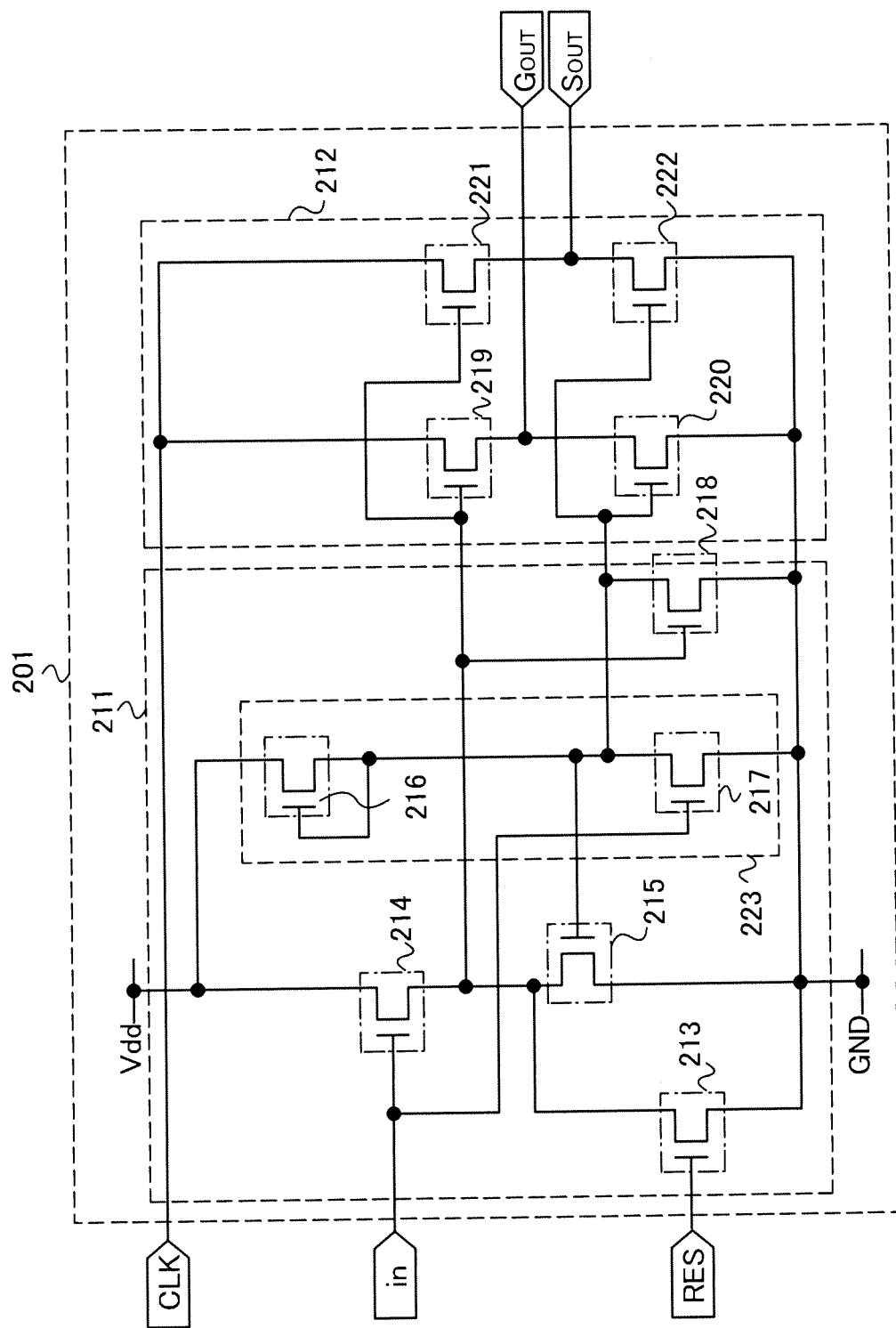


FIG. 4

FIG. 5

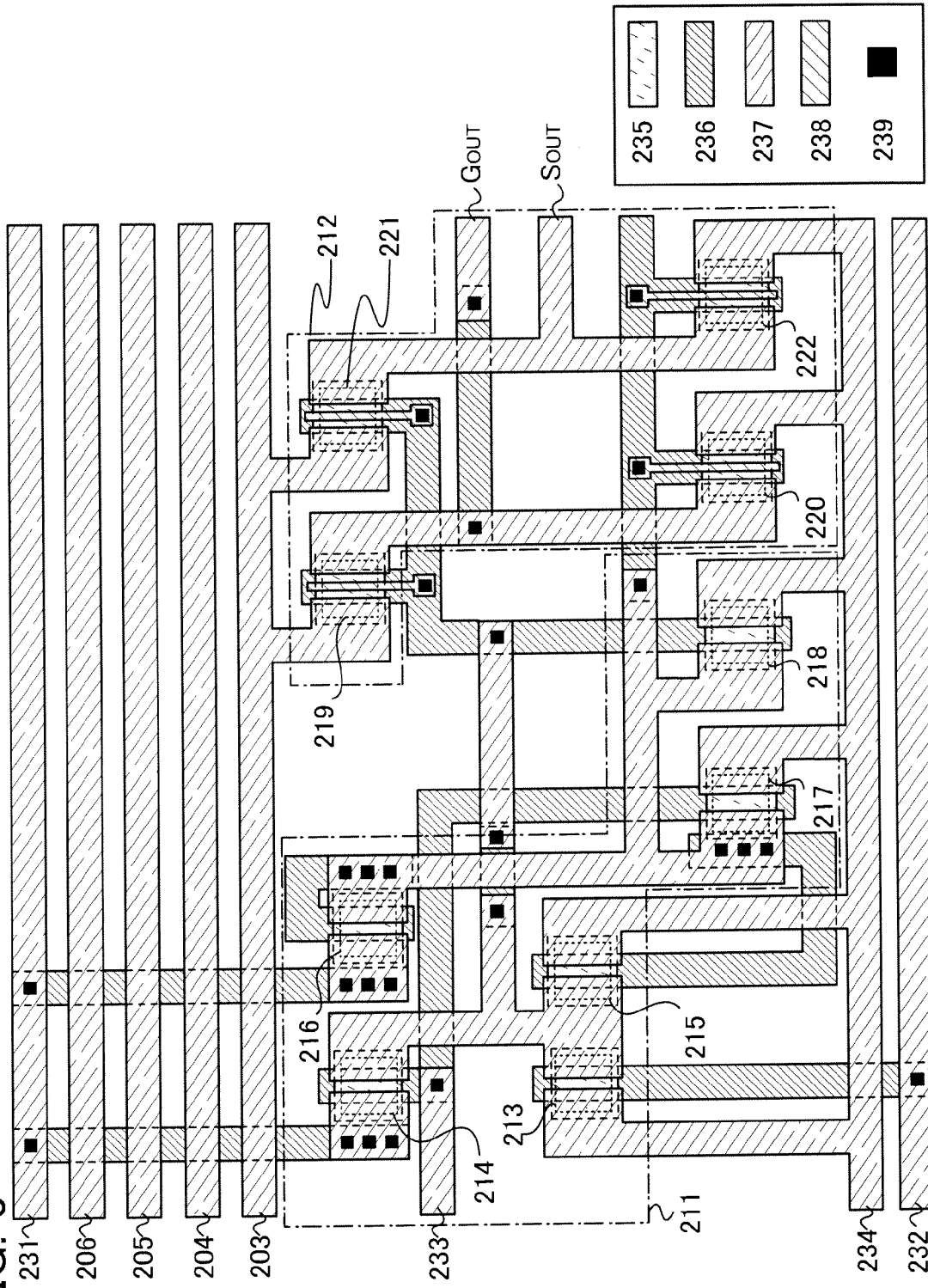


FIG. 6

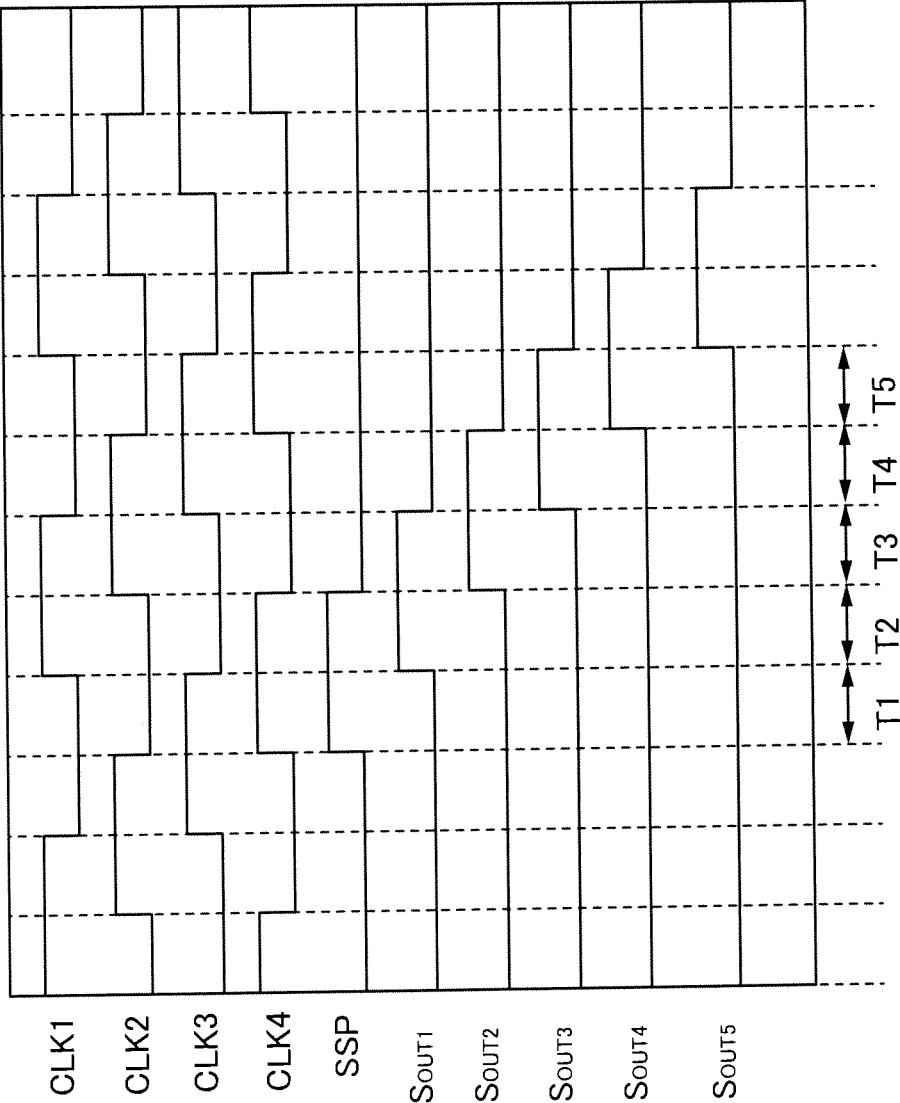


FIG. 7

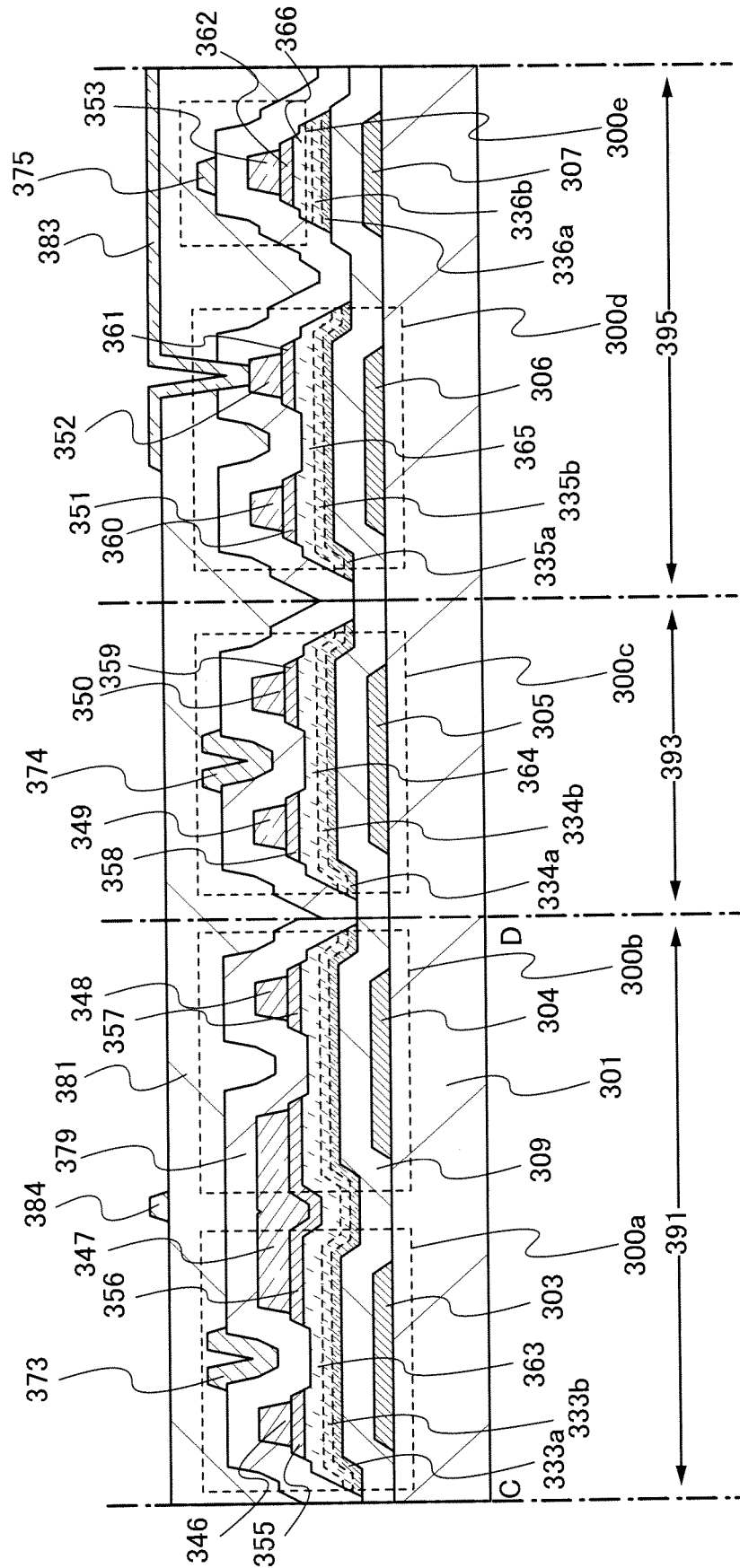


FIG. 8A

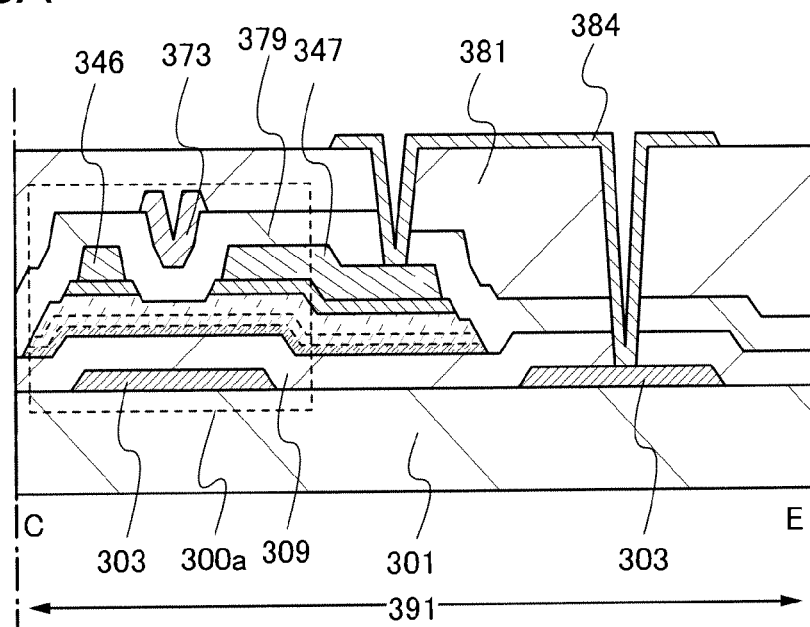


FIG. 8B

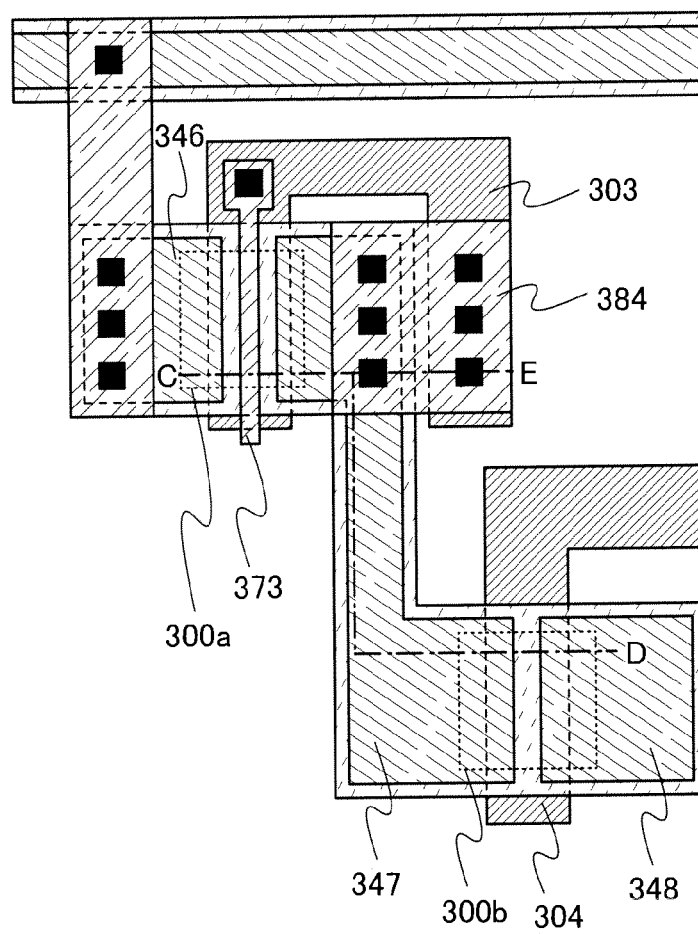


FIG. 9A

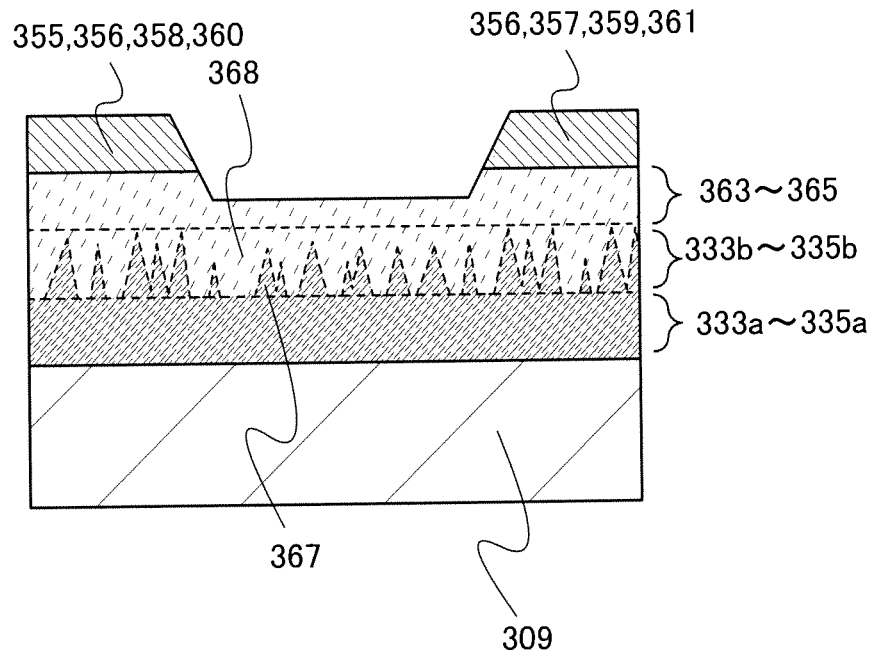


FIG. 9B

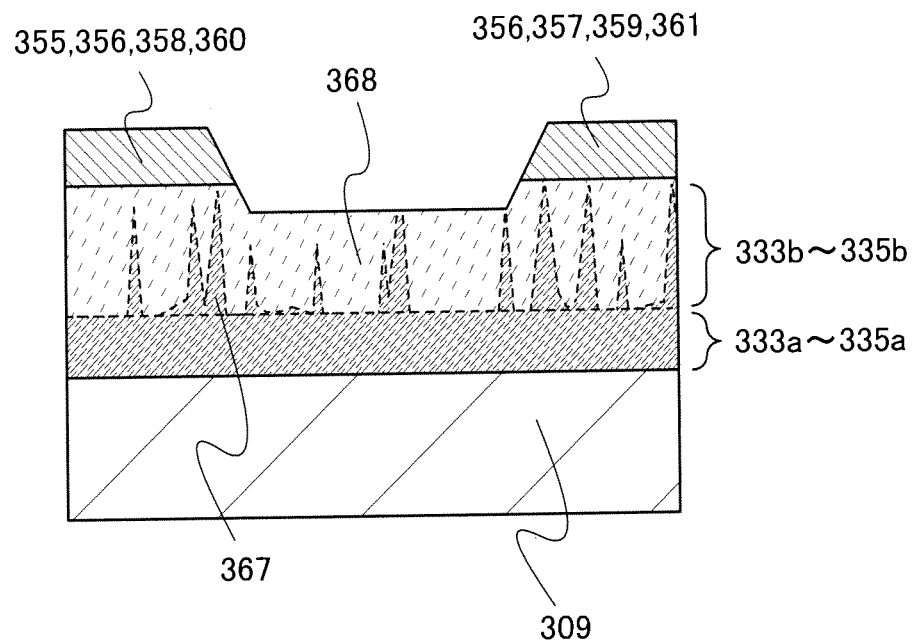


FIG. 11A

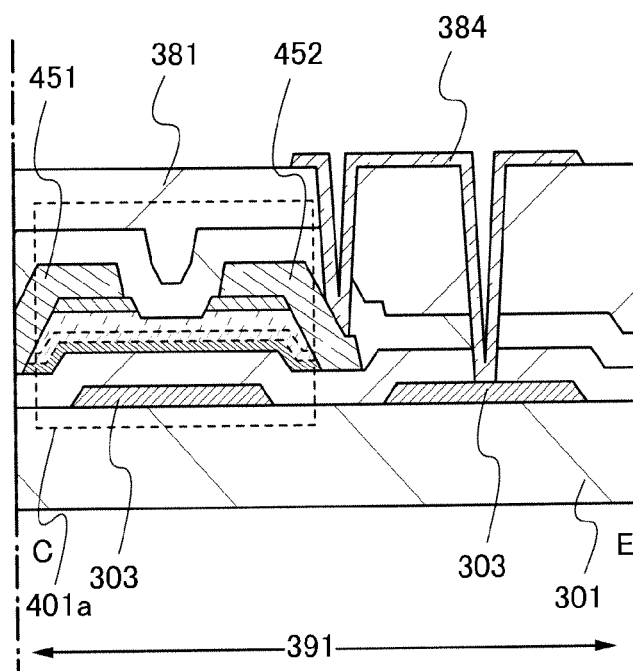


FIG. 11B

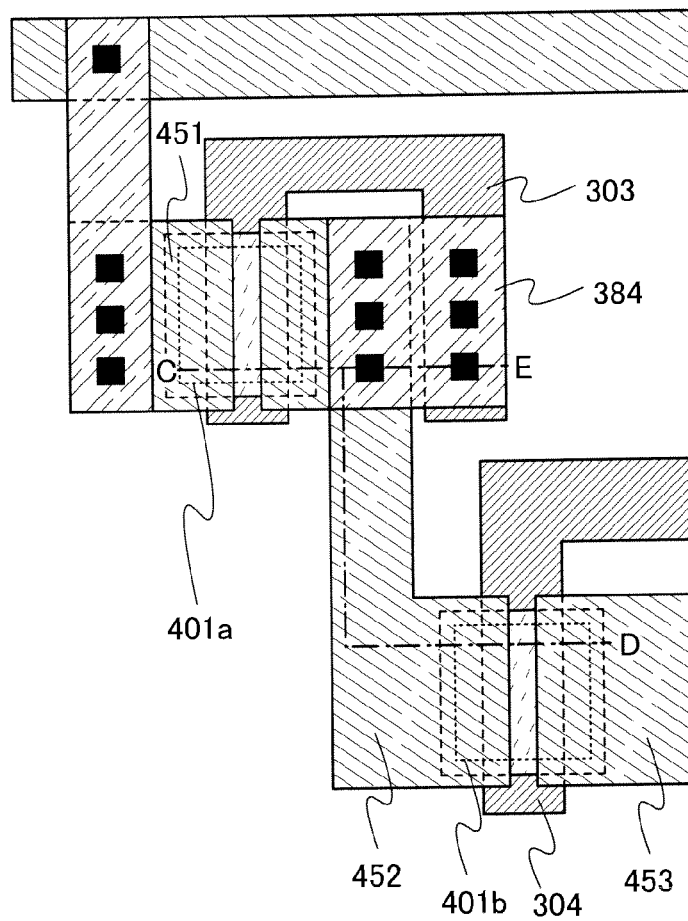


FIG. 12

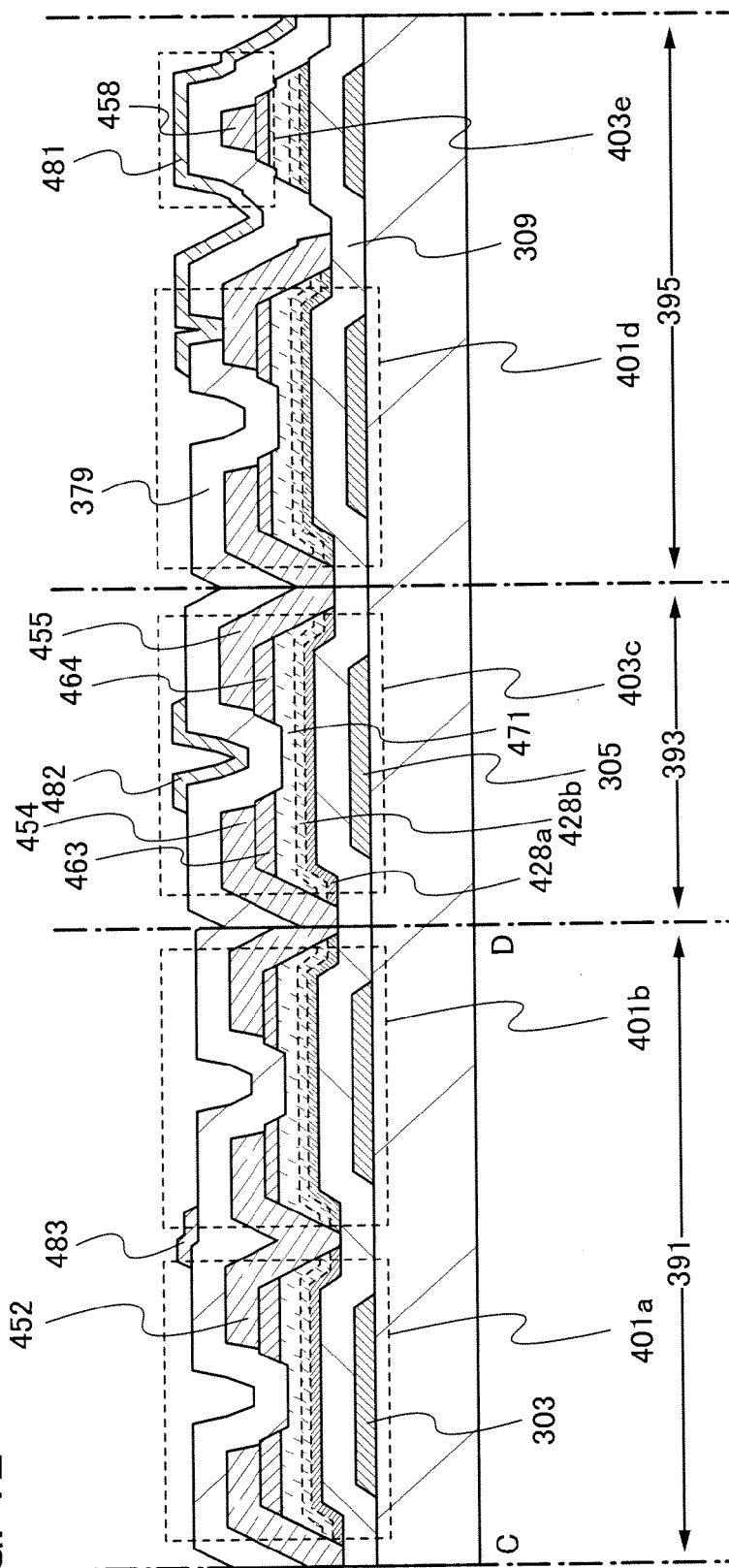


FIG. 13A

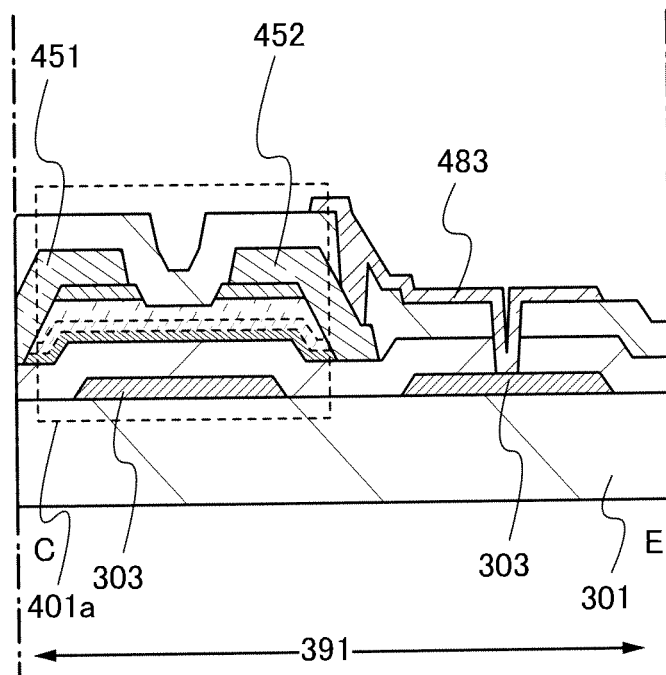


FIG. 13B

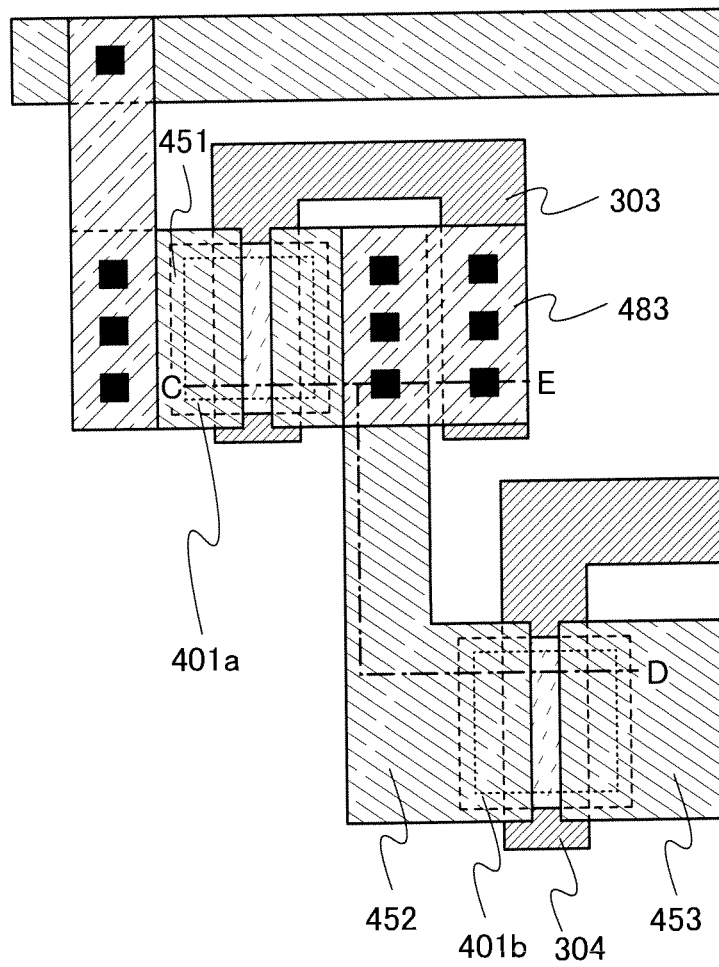


FIG. 14A

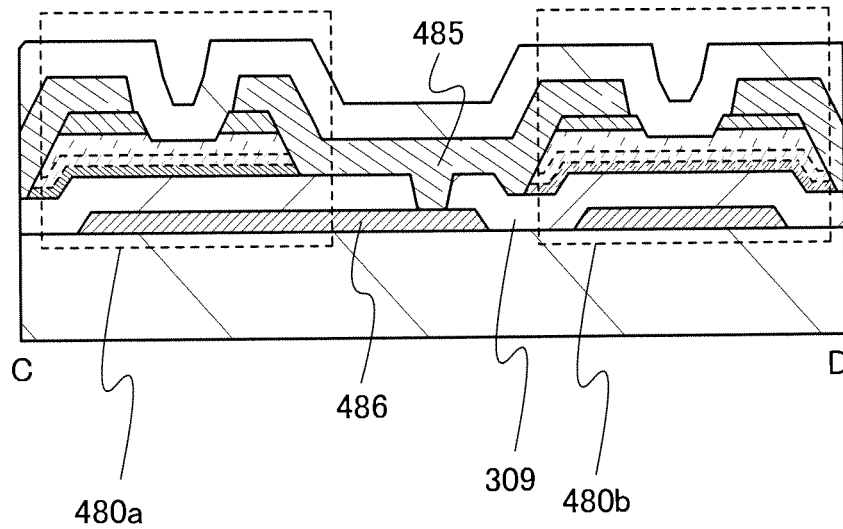


FIG. 14B

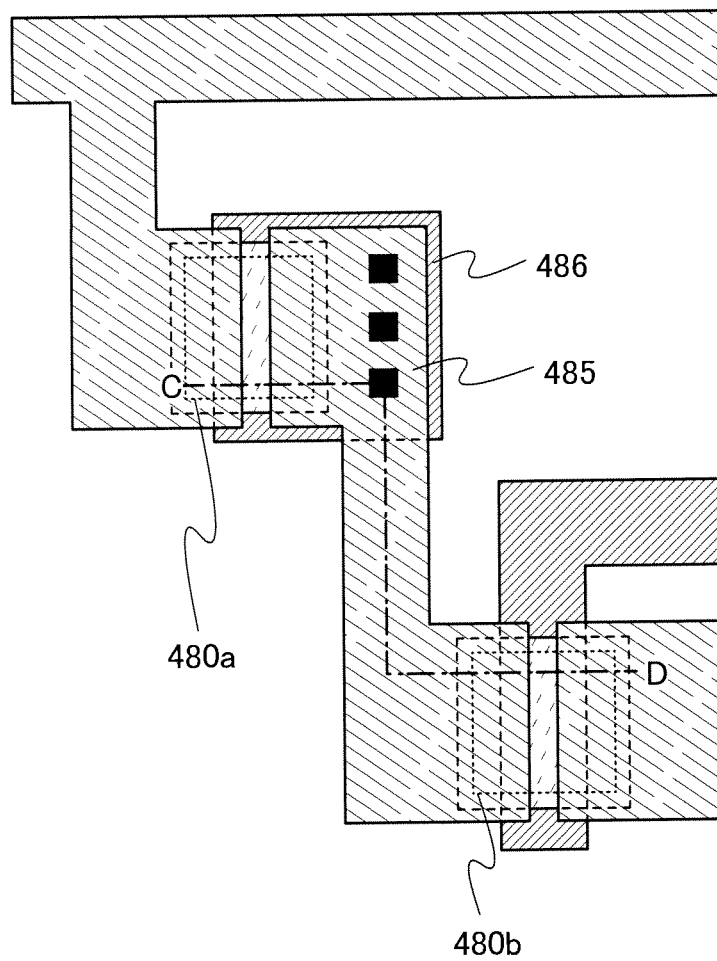


FIG. 15A

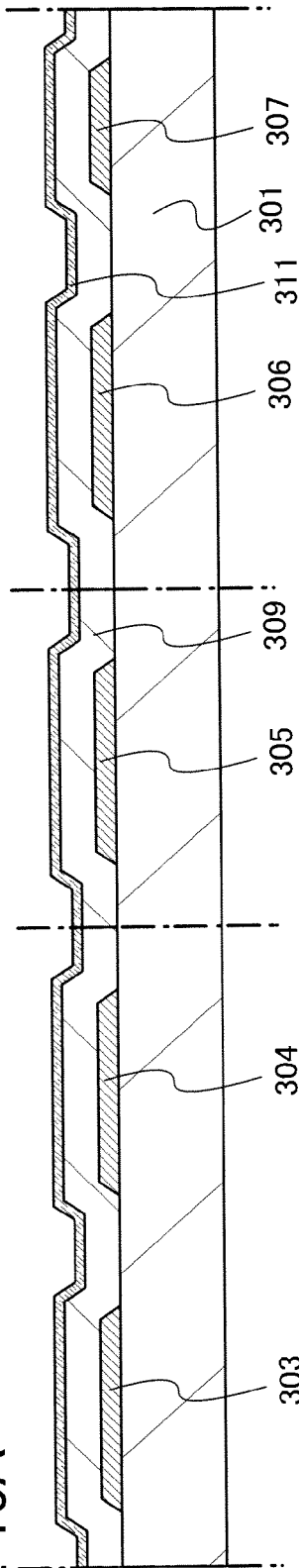


FIG. 15B

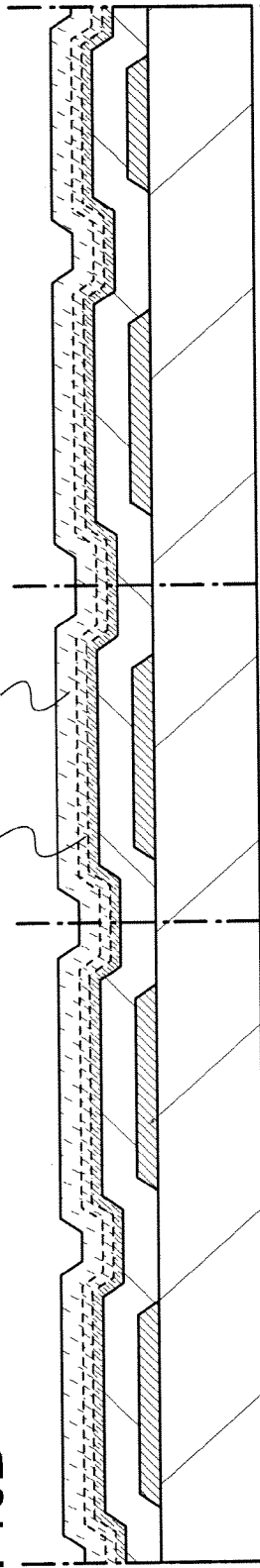
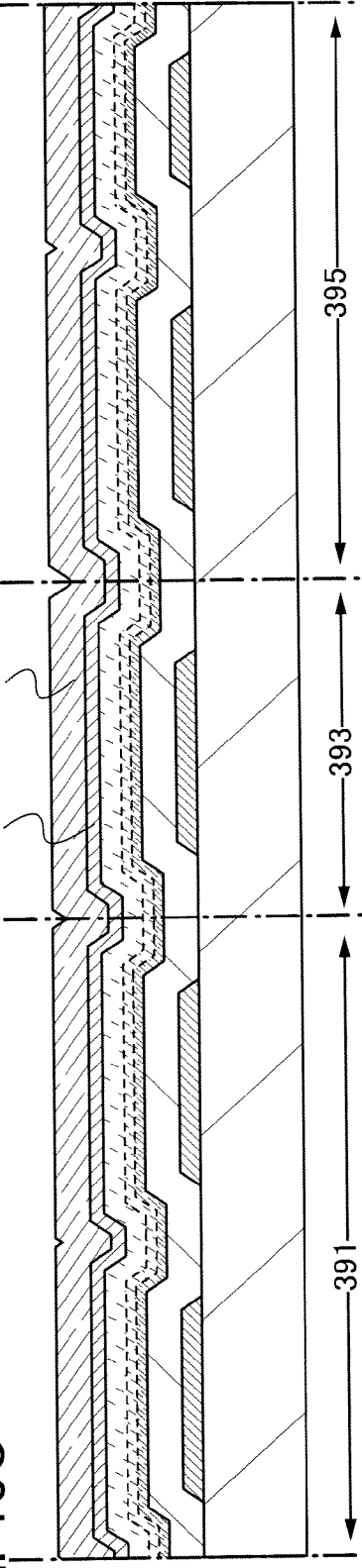


FIG. 15C



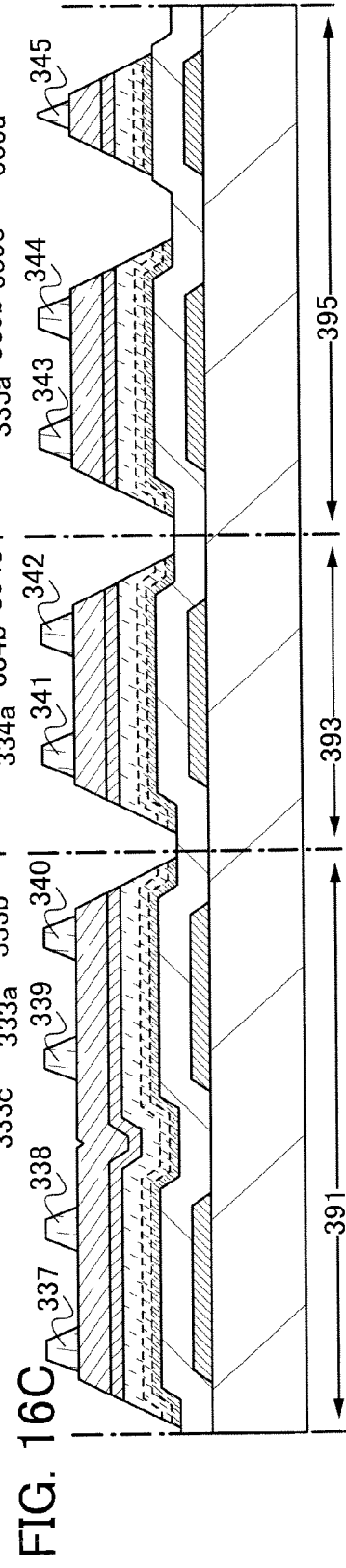
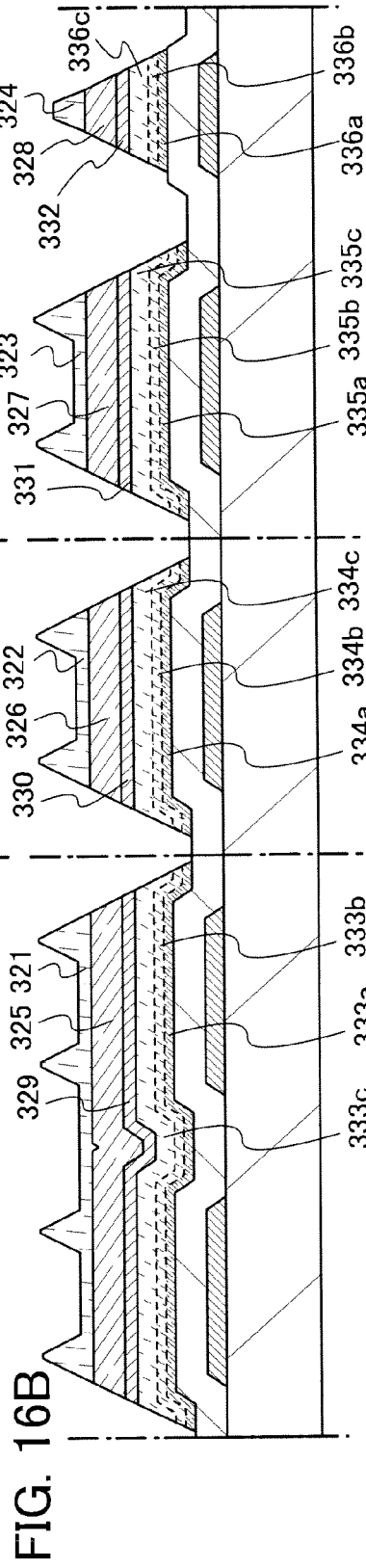
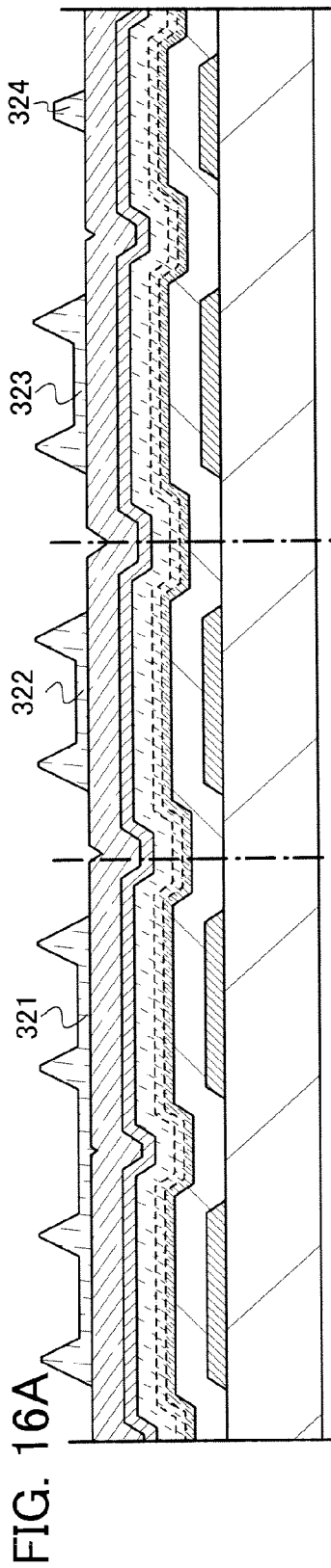


FIG. 17A

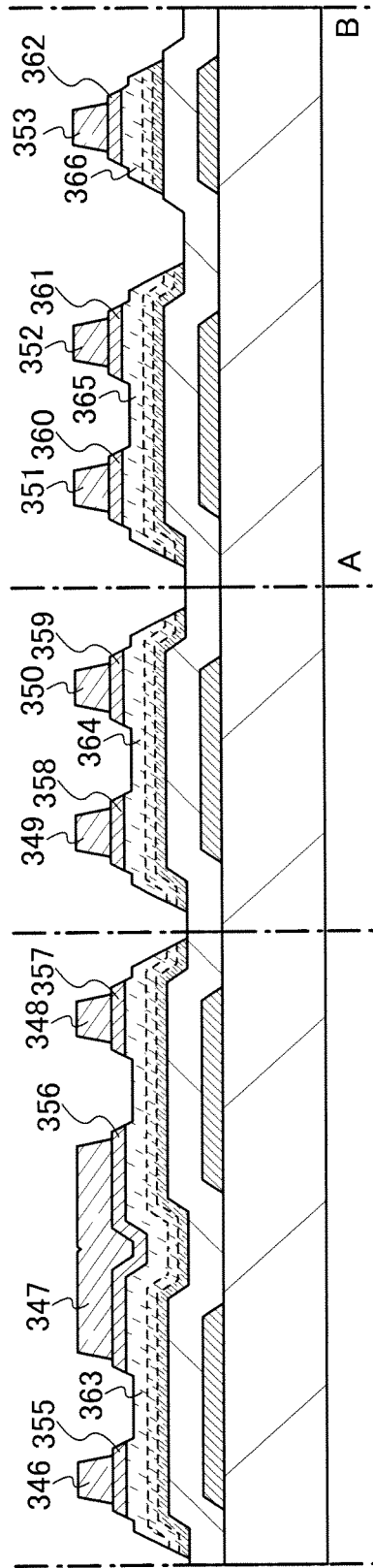


FIG. 17B

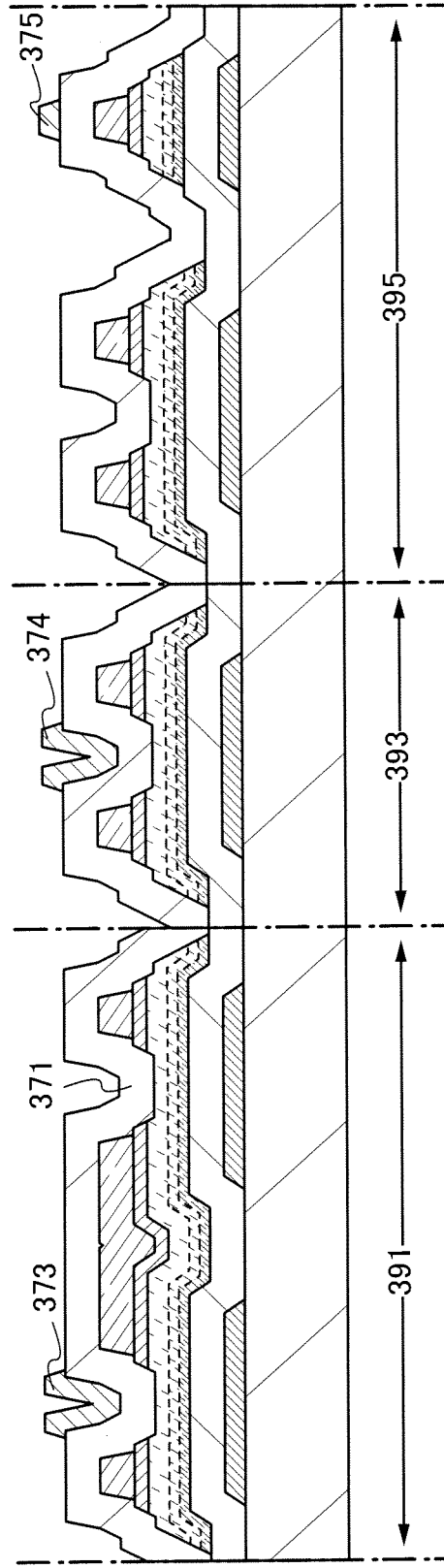


FIG. 18A

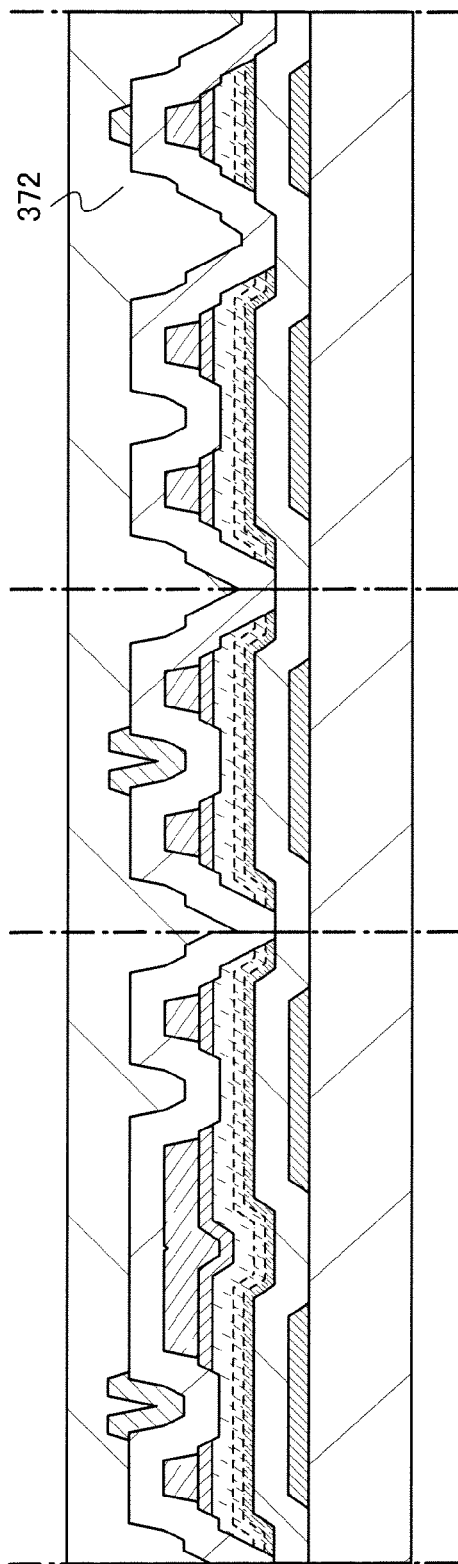
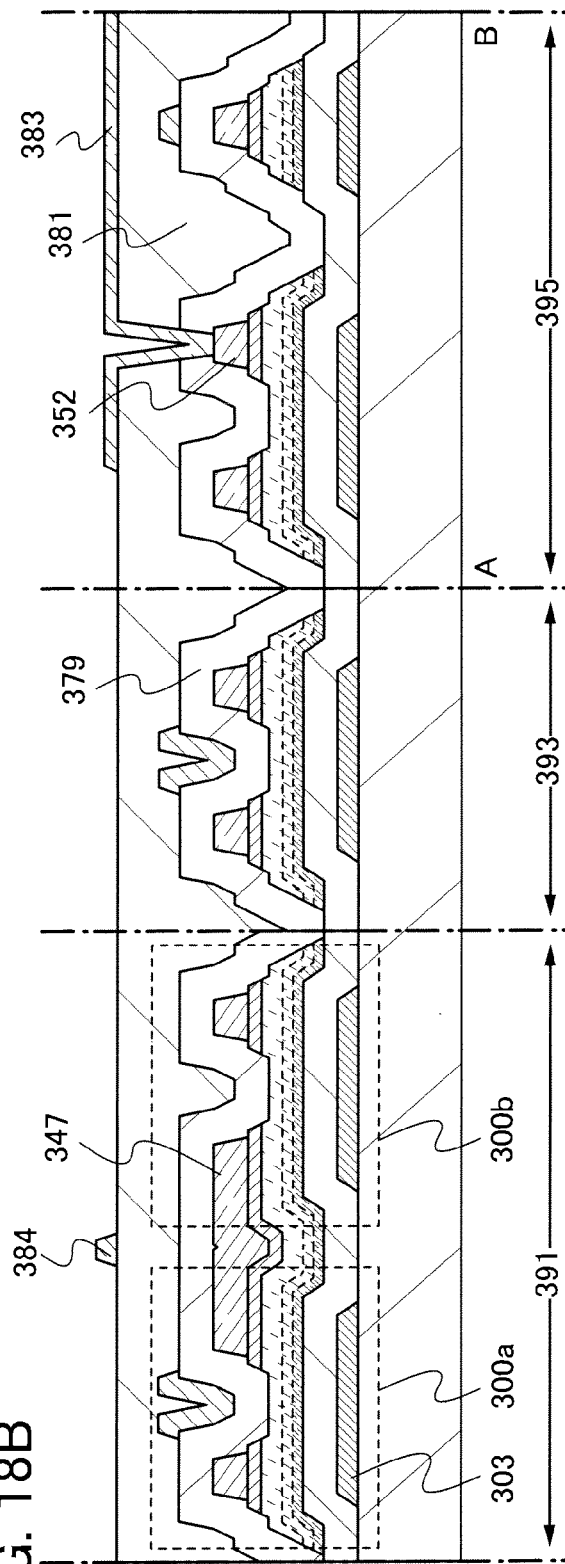


FIG. 18B



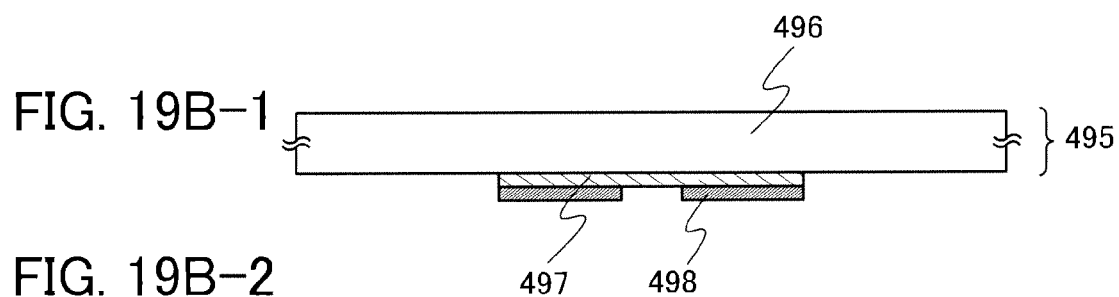
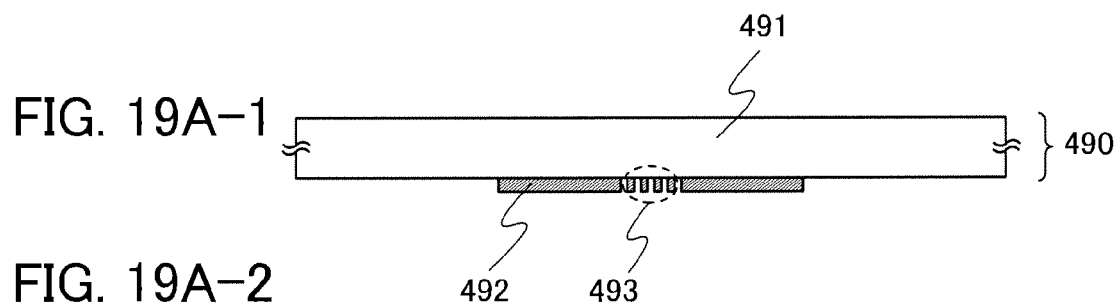


FIG. 20A

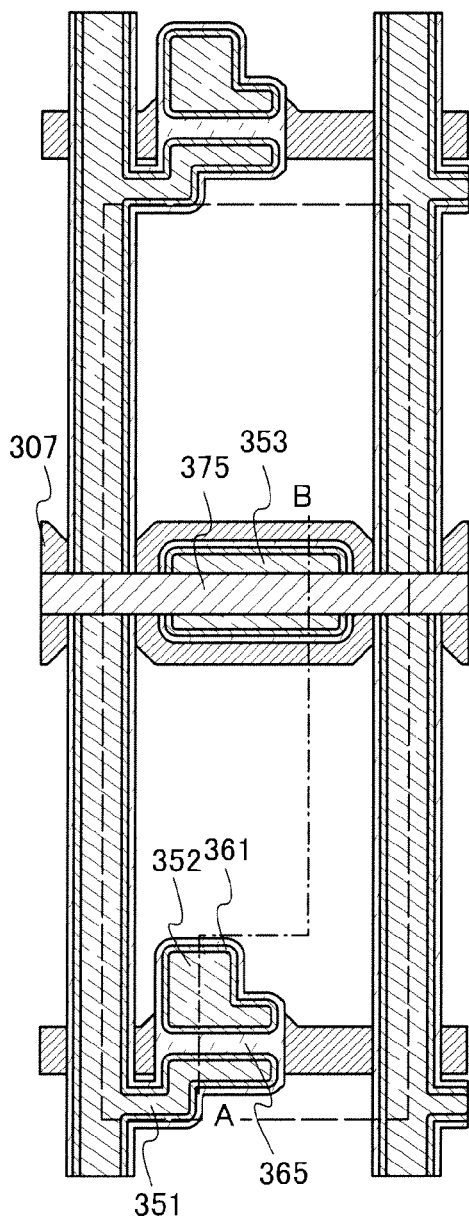


FIG. 20B

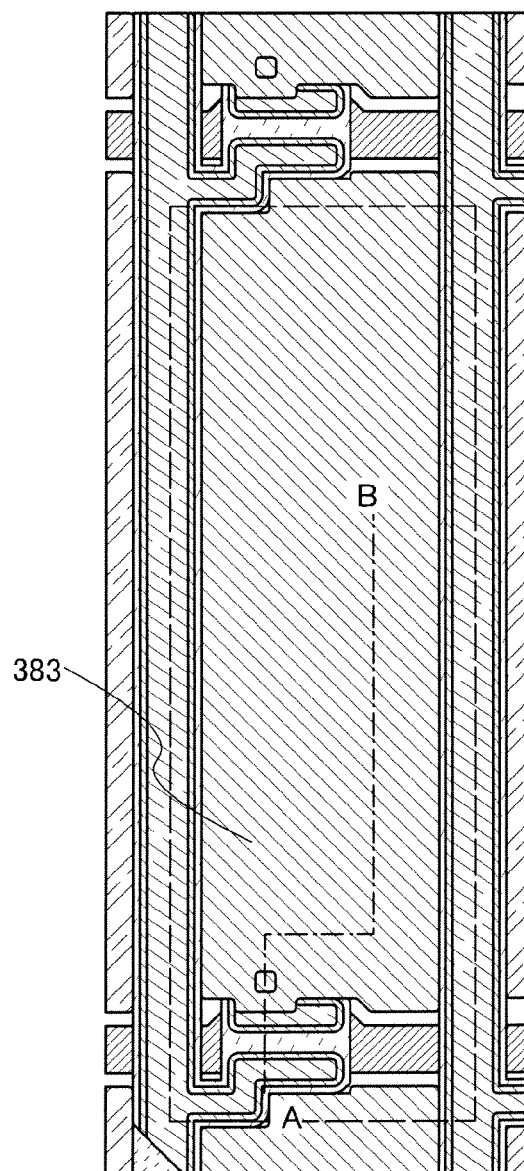


FIG. 21A

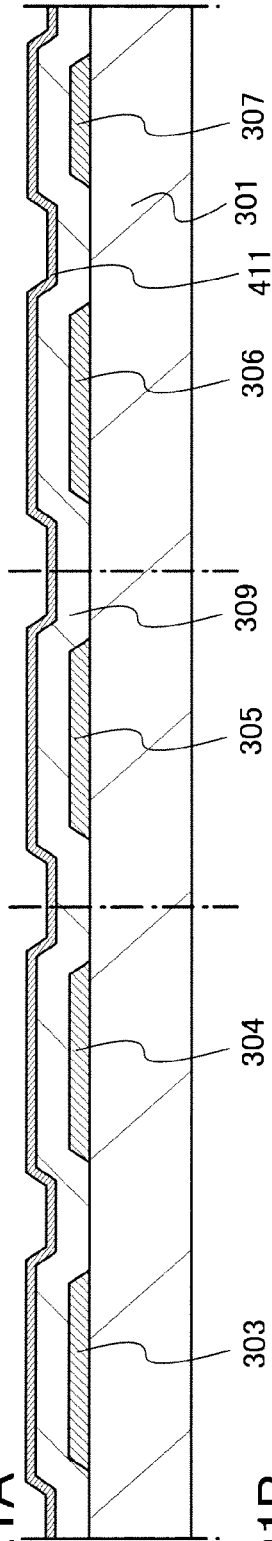


FIG. 21B

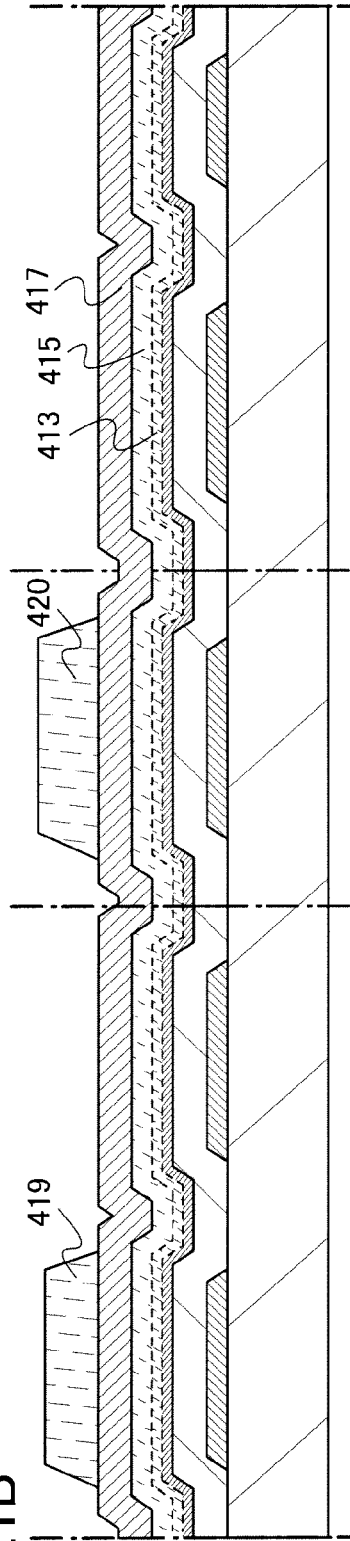
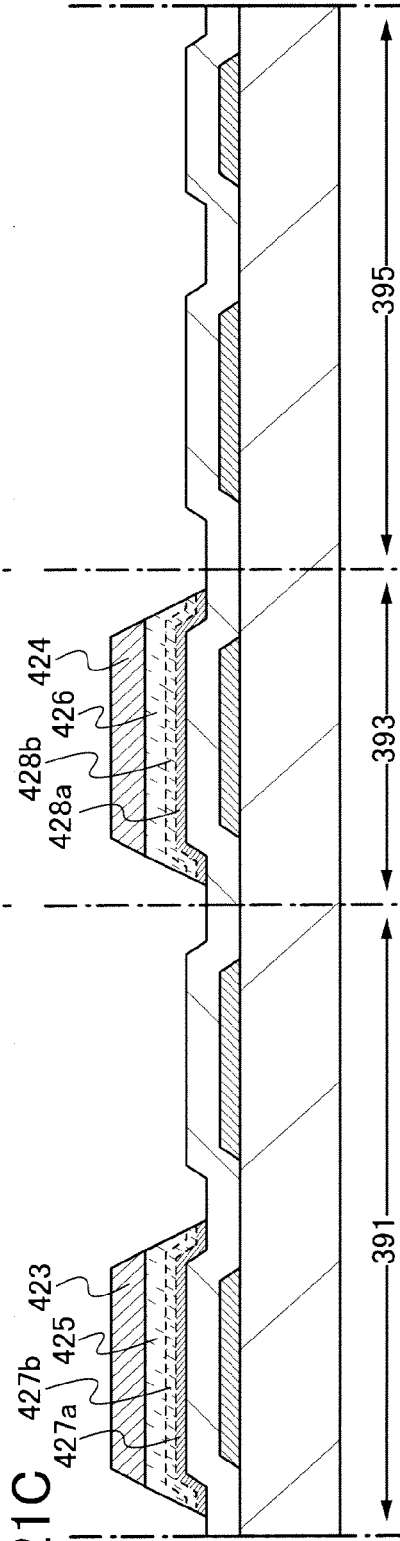


FIG. 21C



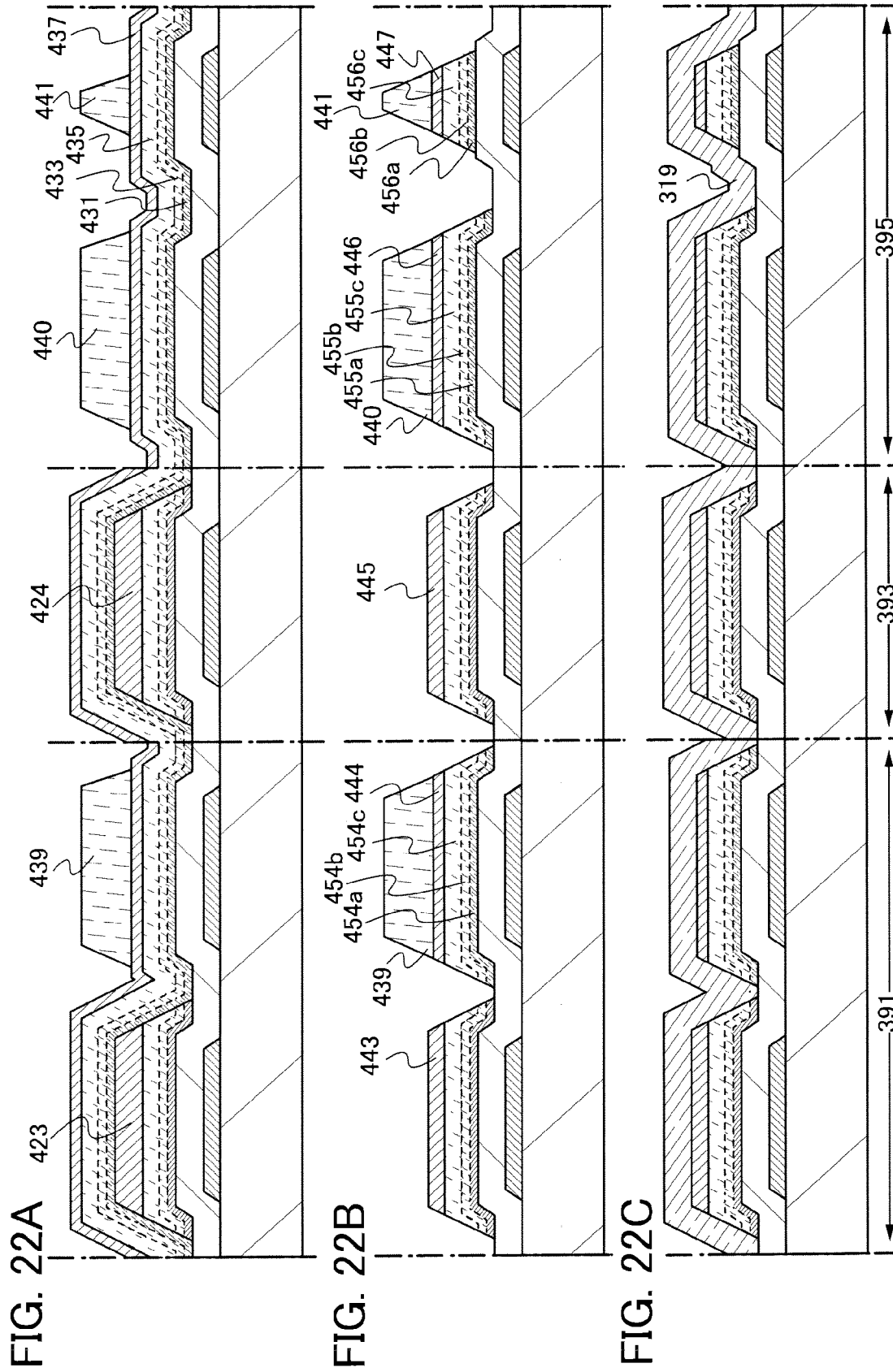


FIG. 23A

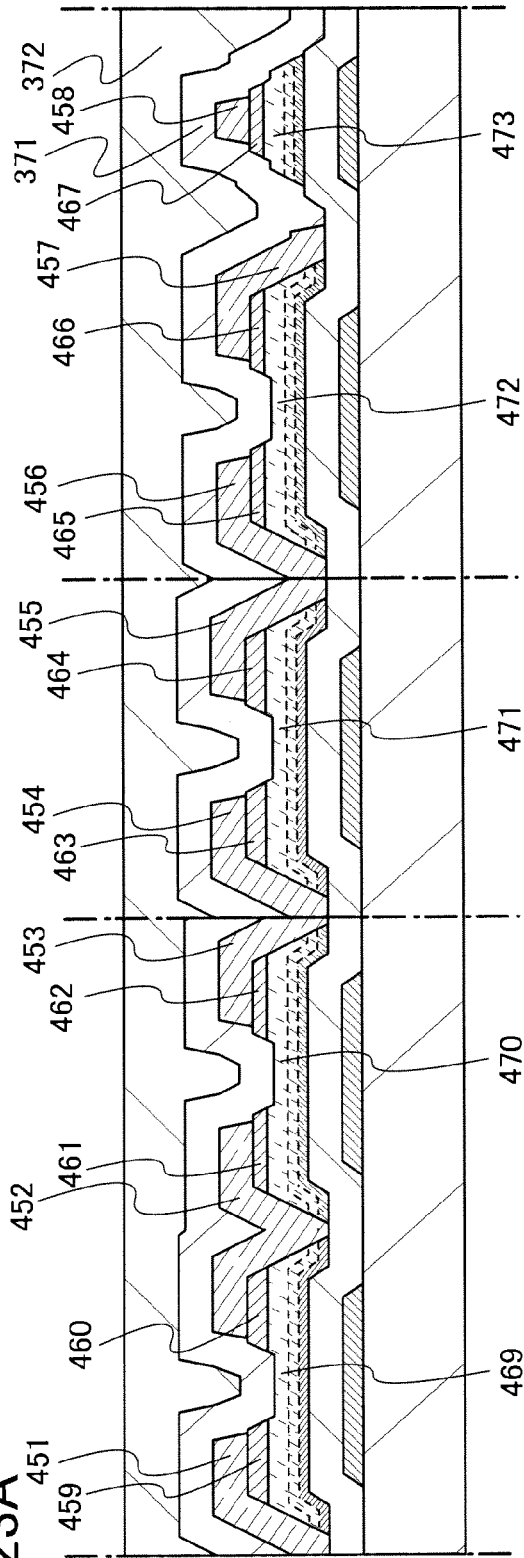
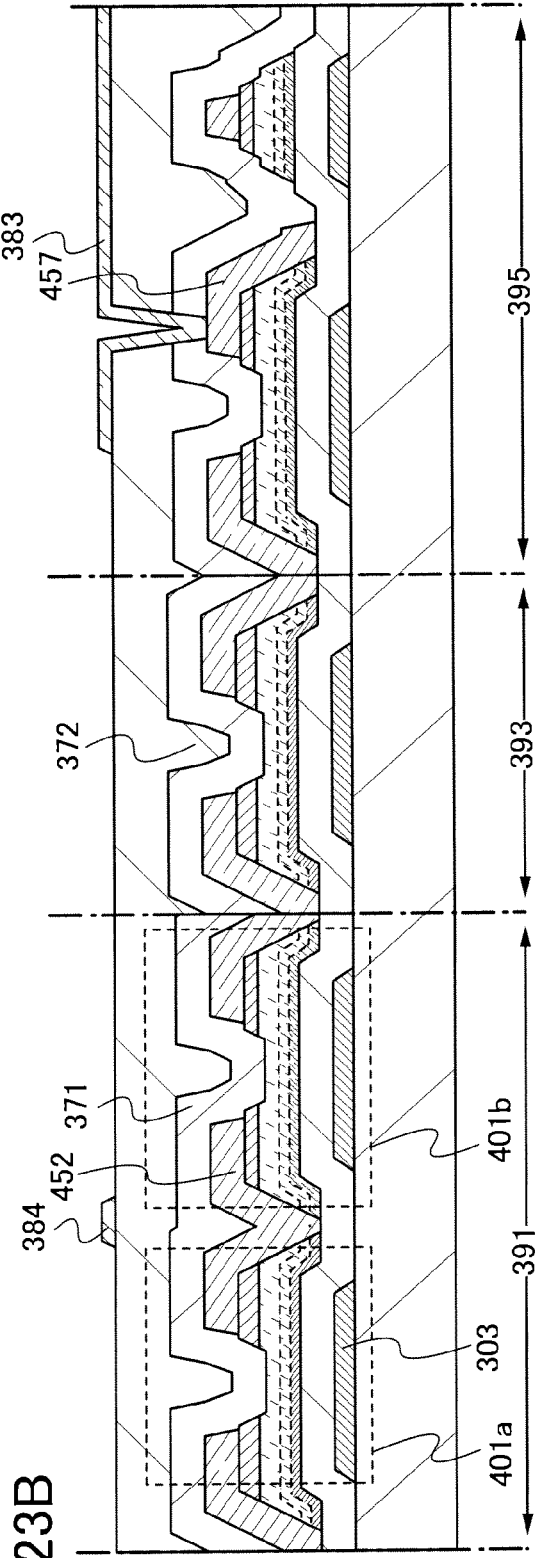


FIG. 23B



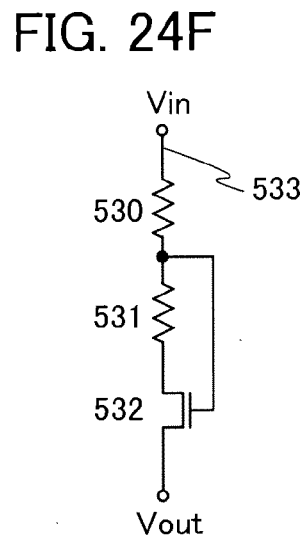
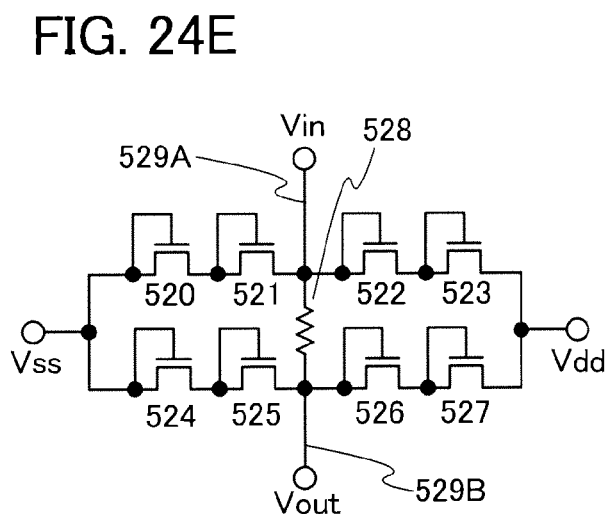
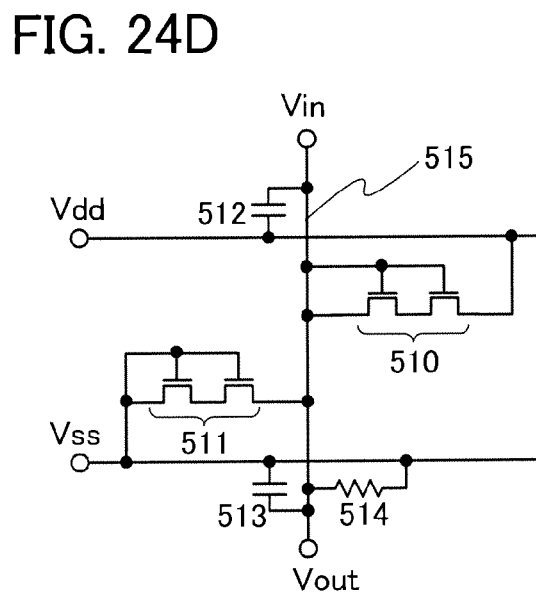
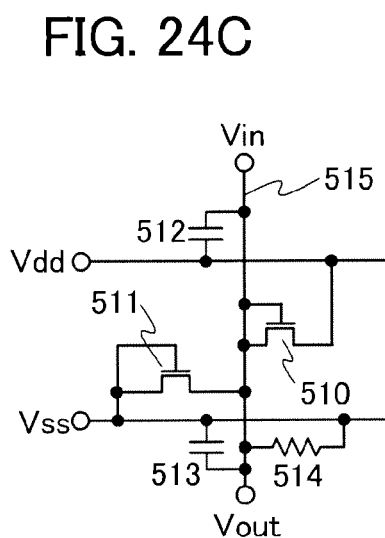
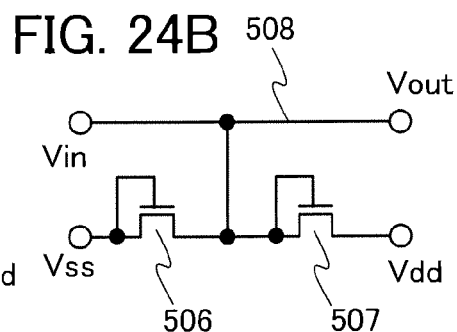
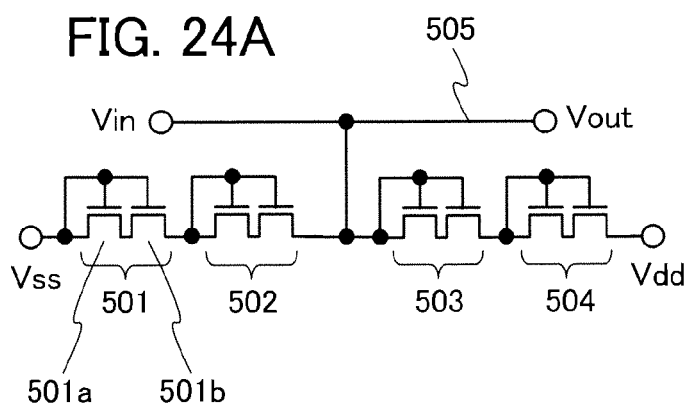


FIG. 25A

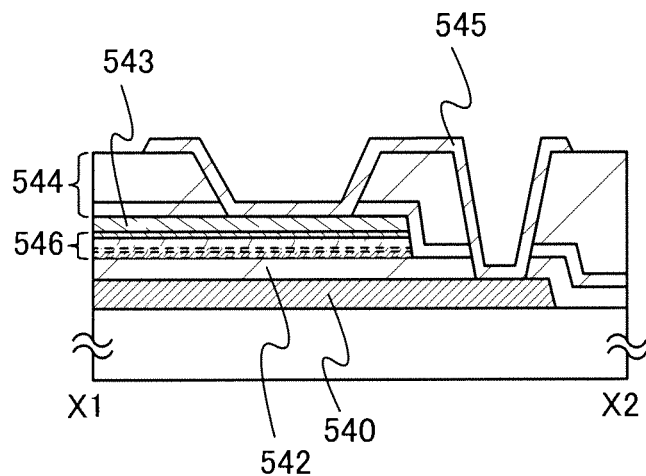


FIG. 25B

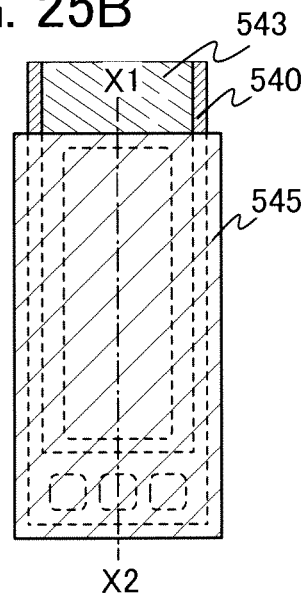


FIG. 25C

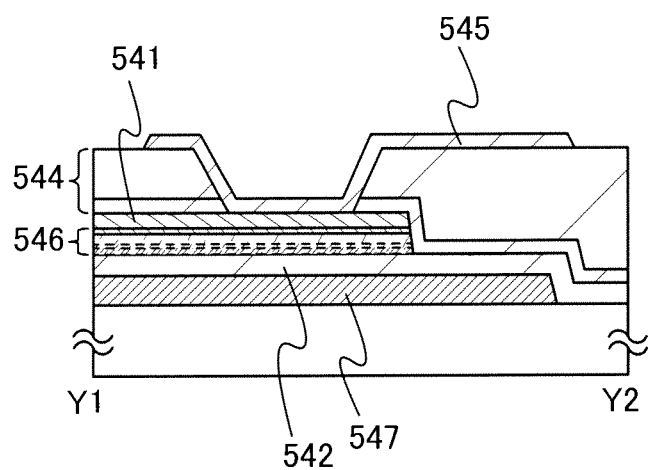


FIG. 25D

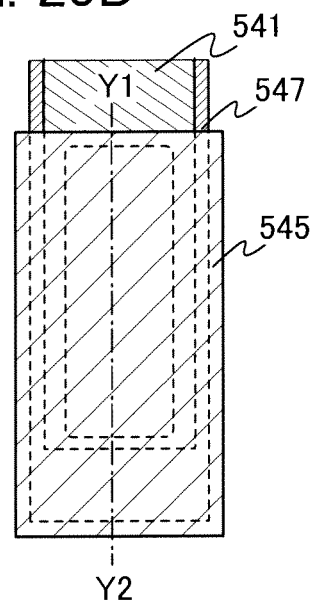


FIG. 26A

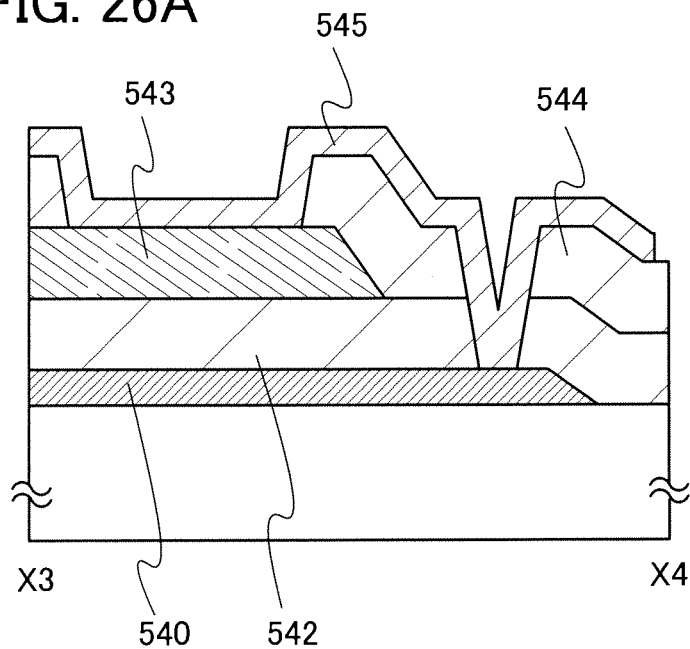


FIG. 26B

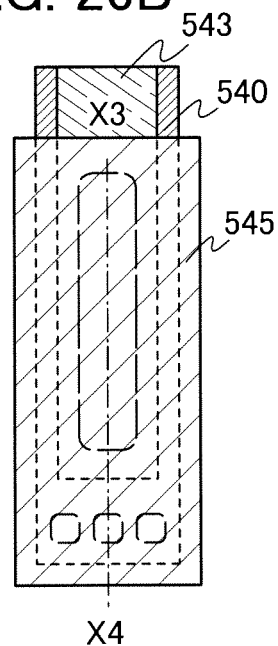


FIG. 26C

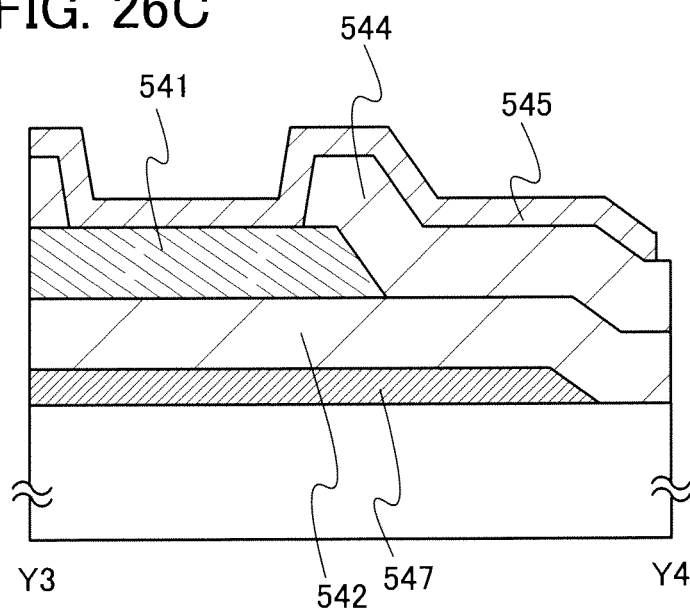


FIG. 26D

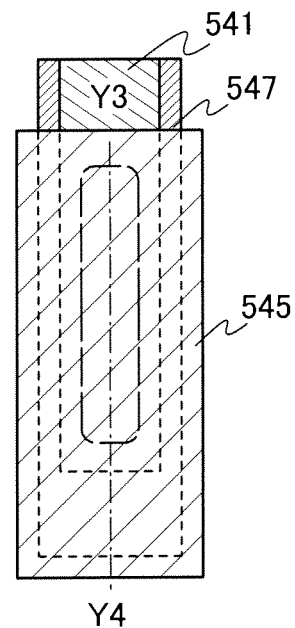


FIG. 27A

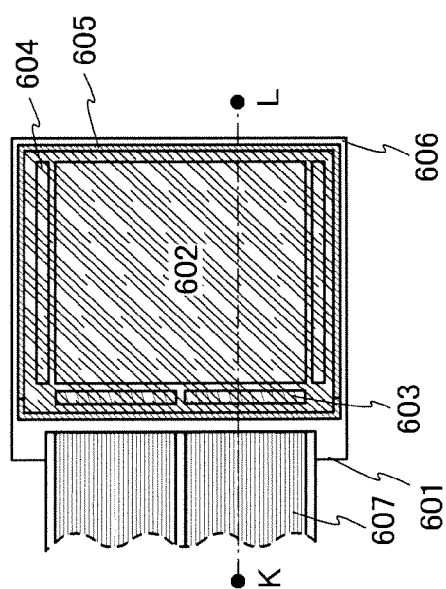


FIG. 27B

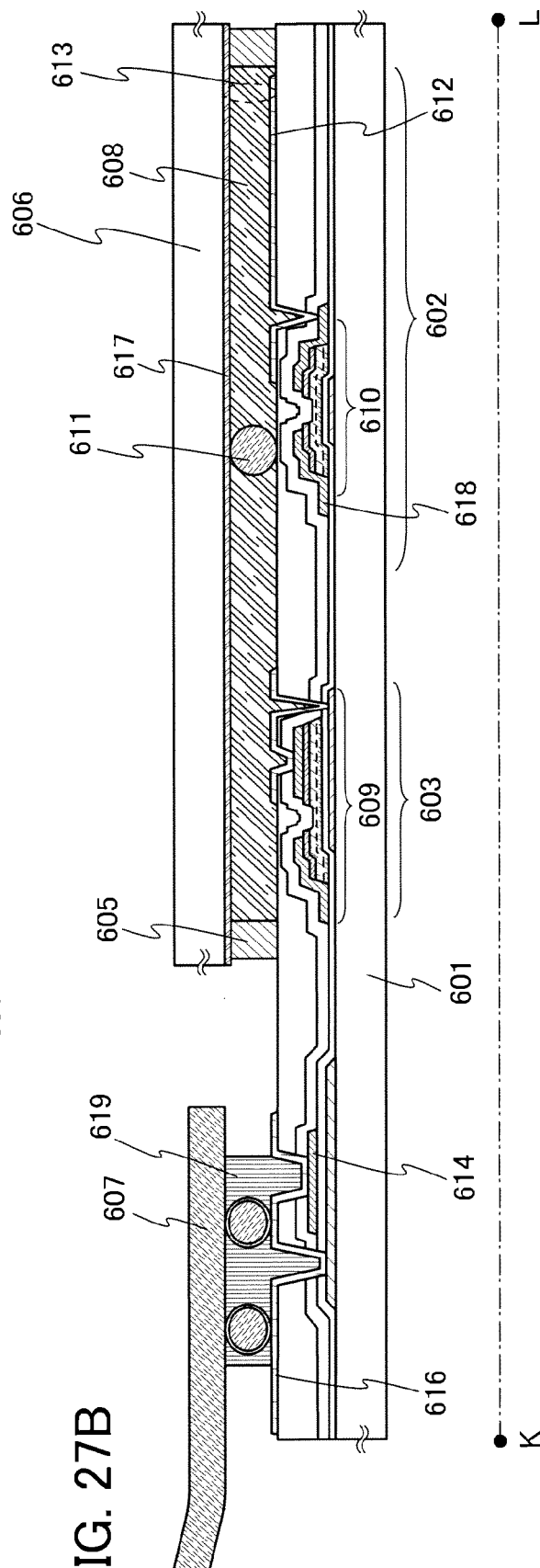


FIG. 28A

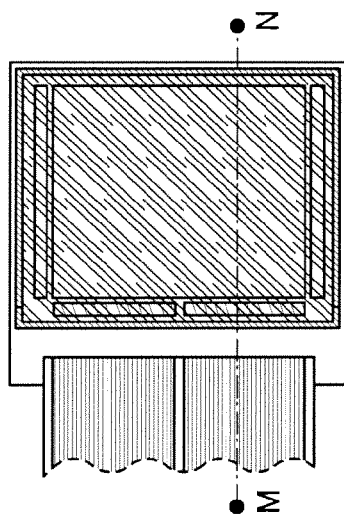


FIG. 28B

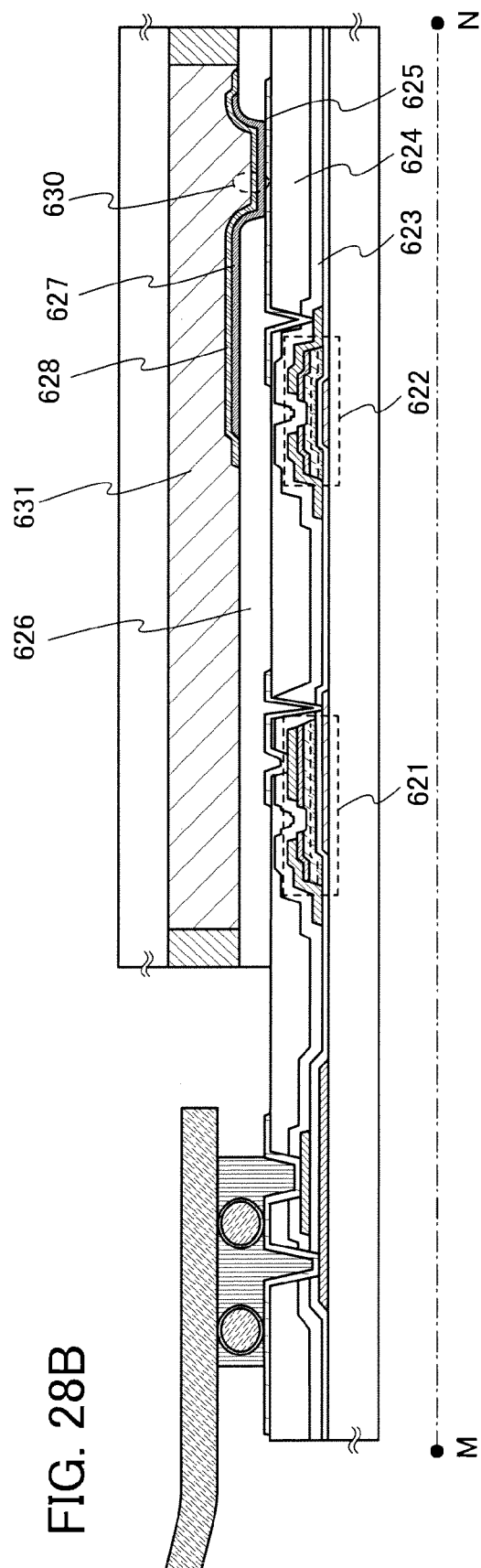


FIG. 29A

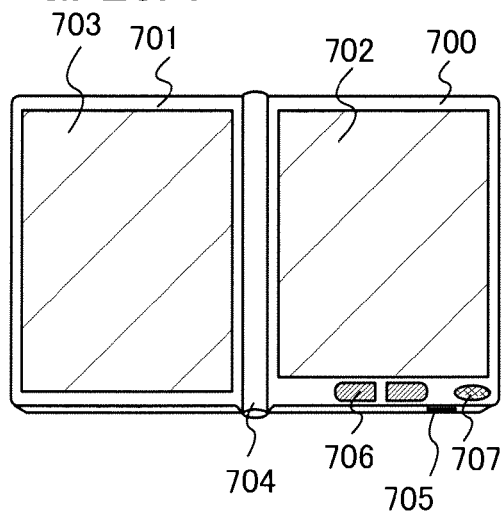


FIG. 29B

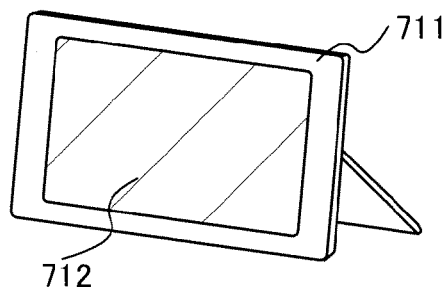


FIG. 29C

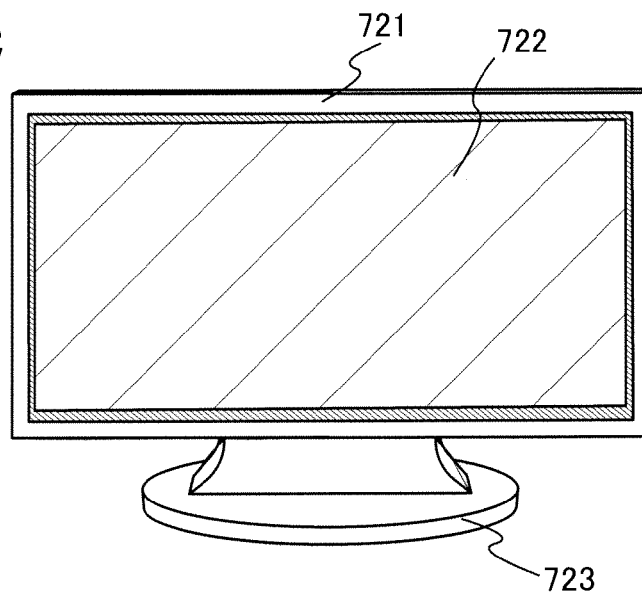
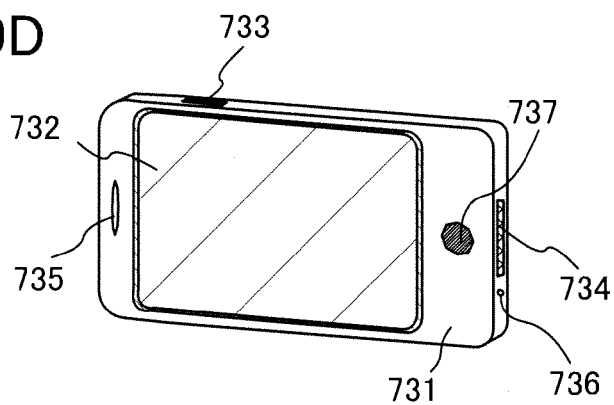


FIG. 29D



1

DISPLAY DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a display device having an inverted staggered thin film transistor in each of a driver circuit and a pixel portion.

2. Description of the Related Art

As one kind of field-effect transistors, a thin film transistor in which a channel formation region is formed in a semiconductor layer formed over a substrate having an insulating surface is known. Techniques in which amorphous silicon, microcrystalline silicon, or polycrystalline silicon is used for semiconductor layers used in thin film transistors have been disclosed. A typical application of a thin film transistor is a liquid crystal television device in which the thin film transistor has been put to the practical use as a switching transistor for each pixel included in a display panel.

Further, for reduction of the cost of a display device, there is a display device of which the number of external components is reduced and in which thin film transistors formed using amorphous silicon or microcrystalline silicon are used for a gate driver (see Patent Document 1).

REFERENCE

Patent Document

[Patent Document 1] Japanese Published Patent Application No. 2005-049832

SUMMARY OF THE INVENTION

The thin film transistor in which an amorphous silicon layer is used for forming a channel formation region has problems such as a low field-effect mobility and a small on current. Further, when the thin film transistor is used for a long-term, there are problems in that the thin film transistor is deteriorated, the threshold voltage is shifted, and on current is lowered. In the case where a driver circuit such as a gate driver is formed using the thin film transistors in which an amorphous silicon layer is used for the channel formation region, the width of the channel formation region is widened, and the area occupied by the thin film transistors is enlarged. Thus, a sufficient on current is maintained even when on current is lowered due to the shift of the threshold voltage.

Alternatively, the number of the thin film transistors included in the driver circuit is increased and an operating period of each of the thin film transistors is shortened, so that deterioration of the thin film transistors is reduced and a sufficient on current is maintained.

Therefore, in a display device of which driver circuit is formed using thin film transistors in which an amorphous silicon layer is used for the channel formation region, the area occupied by the driver circuit is large, narrowing a frame of the display device is prevented, and the area of a pixel portion which is a display region is reduced.

On the other hand, the thin film transistor in which a microcrystalline silicon layer is used for the channel formation region has problems in that, whereas the field-effect mobility is higher than that of the thin film transistor using amorphous silicon, the off current is high, so that sufficient switching characteristics cannot be obtained.

The thin film transistor in which a polycrystalline silicon layer is used for a channel formation region has characteristics in that the field-effect mobility is far higher than those of

2

the above-referenced two kinds of thin film transistors and high on current can be obtained. Because of such characteristics, this thin film transistor can be used not only as a switching transistor provided in a pixel but also as a transistor provided in a driver circuit for which high-speed operation is required.

However, the thin film transistor in which a polycrystalline silicon layer is used for the channel formation region has a problem in that the manufacturing cost becomes higher than that of the thin film transistor using an amorphous silicon layer due to the necessity for a step of crystallizing a semiconductor layer. For example, the laser annealing technique involved in the process for manufacturing a polycrystalline silicon layer has a problem in that the irradiated area with a laser beam is small and large-screen liquid crystal panels cannot be produced efficiently.

In view of the above problems, one object of an embodiment of the present invention is to provide a display device of which manufacturing cost can be reduced and of which display characteristics of an image are excellent. Further, another object of an embodiment of the present invention is to provide a display device of which manufacturing cost can be reduced and of which frame can be narrowed.

The present invention relates to a display device that includes a driver circuit portion and a pixel portion. The driver circuit portion includes a logic circuit portion and a switch portion or a buffer portion. TFTs included in the driver circuit portion and the pixel portion are inverted staggered TFTs having the same polarity. The switch portion or the buffer portion is formed using the inverted staggered TFTs through which a large amount of on current can flow, and the logic circuit portion is formed using an inverter circuit (hereinafter referred to as an EDMOS circuit) including a depletion type TFT and an enhancement type TFT.

As a TFT through which a large amount of on current can flow, a dual-gate type inverted staggered TFT or a depletion type inverted staggered TFT is used.

An EDMOS circuit includes two or more inverted staggered TFTs of which threshold voltages are different from one another, typically a depletion type TFT and an enhancement type TFT. The depletion type TFT is formed using a dual-gate type inverted staggered thin film transistor provided with a first gate electrode, a first gate insulating layer, a semiconductor layer formed over the first gate insulating layer, a second gate insulating layer formed over the semiconductor layer, and a second gate electrode formed over the second gate insulating layer; therefore, the threshold voltage is controlled and the EDMOS circuit can be formed.

Alternatively, as the depletion type TFT, an inverted staggered TFT including a semiconductor layer in which an impurity element serving as a donor is added to the channel formation region is used, and as the enhancement type TFT, a semiconductor layer in which an impurity element serving as a donor is not added to the channel formation region is used; thus, the EDMOS circuit can be formed.

Alternatively, as the depletion type TFT, an inverted staggered TFT including a semiconductor layer in which an impurity element serving as an acceptor is not added to the channel formation region is used, and as the enhancement type TFT, a TFT including a semiconductor layer in which an impurity element serving as an acceptor is added to the channel formation region is used; thus, the EDMOS circuit can be formed.

Further, the inverted staggered TFT manufactured in the display device of the present invention includes a gate electrode, a gate insulating layer formed over the gate electrode, a semiconductor layer formed over the gate insulating layer, an impurity semiconductor layers serving as a source region

and a drain region formed over the semiconductor layer, and a wiring. As to the semiconductor layer formed over the gate insulating layer, a microcrystalline layer is formed on the gate insulating layer side, and an amorphous semiconductor layer is formed on the source region and the drain region side. Alternatively, the microcrystalline semiconductor layer is formed on the gate insulating layer side, and the amorphous semiconductor layer is formed on the source region and the drain region side, and further, conical or pyramidal shape microcrystalline semiconductor regions and amorphous semiconductor regions filling the space except the microcrystalline semiconductor regions are formed between the microcrystalline semiconductor layer and the amorphous semiconductor layer. Therefore, in the inverted staggered TFT, on current can be increased and off current thereof can be lowered.

Note that on current refers to current which flows between a source electrode and a drain electrode while a transistor is in an on-state. For example, in the case of an n-type transistor, on current refers to current, which flows between the source electrode and the drain electrode when a gate voltage is higher than a threshold voltage of the transistor.

Further, off current refers to current which flows between the source electrode and the drain electrode while the transistor is in an off-state. For example, in the case of an n-type transistor, off current refers to current that flows between the source electrode and the drain electrode when the gate voltage is lower than the threshold voltage of the transistor.

Note that a display device in this specification means an image display device, a light-emitting device, or a light source (including a lighting device). Further, the display device includes any of the following modules in its category: a module including a connector such as an flexible printed circuit (FPC), tape automated bonding (TAB) tape, or a tape carrier package (TCP); a module having TAB tape or a TCP which is provided with a printed wiring board at the end of the TAB tape or TCP; and a module having an integrated circuit (IC) which is directly mounted on a display element by a chip on glass (COG) method.

According to the present invention, the display characteristics of an image can be improved while the cost of the display device can be reduced. Further, the frame of the display device can be narrowed, and thus, the display region of the display device can be enlarged.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A and 1B are block diagrams each illustrating a whole display device according to an embodiment of the present invention.

FIG. 2 is a diagram illustrating arrangement of wirings, input terminals, and the like of a display device according to an embodiment of the present invention.

FIG. 3 is a block diagram illustrating a structure of a shift register circuit.

FIG. 4 is a diagram illustrating an example of a flip-flop circuit.

FIG. 5 is a layout view (top view) of the flip-flop circuit.

FIG. 6 is a timing chart illustrating operation of the shift register circuit.

FIG. 7 is a cross-sectional view of a display device according to an embodiment of the present invention.

FIGS. 8A and 8B are a cross-sectional view and a top view, respectively, which illustrate a display device according to an embodiment of the present invention.

FIGS. 9A and 9B are cross-sectional views each illustrating a thin film transistor of a display device according to an embodiment of the present invention.

FIG. 10 is a cross-sectional view illustrating a display device according to an embodiment of the present invention.

FIGS. 11A and 11B are a cross-sectional view and a top view, respectively, which illustrate a display device according to an embodiment of the present invention.

FIG. 12 is a cross-sectional view illustrating a display device according to an embodiment of the present invention.

FIGS. 13A and 13B are a cross-sectional view and a top view, respectively, which illustrate a display device according to an embodiment of the present invention.

FIGS. 14A and 14B are a cross-sectional view and a top view, respectively, which illustrate a driver circuit of a display device according to an embodiment of the present invention.

FIGS. 15A to 15C are cross-sectional views illustrating a method for manufacturing a display device according to an embodiment of the present invention.

FIGS. 16A to 16C are cross-sectional views illustrating a method for manufacturing a display device according to an embodiment of the present invention.

FIGS. 17A and 17B are cross-sectional views illustrating a method for manufacturing a display device according to an embodiment of the present invention.

FIGS. 18A and 18B are cross-sectional views illustrating a method for manufacturing a display device according to an embodiment of the present invention.

FIGS. 19A-1 to 19B-2 are views illustrating multi-tone masks which can be applied to a method for manufacturing a display device according to an embodiment of the present invention.

FIGS. 20A and 20B are plan views illustrating a method for manufacturing a display device according to an embodiment of the present invention.

FIGS. 21A to 21C are cross-sectional views illustrating a method for manufacturing a display device according to an embodiment of the present invention.

FIGS. 22A to 22C are cross-sectional views illustrating a method for manufacturing a display device according to an embodiment of the present invention.

FIGS. 23A and 23B are cross-sectional views illustrating a method for manufacturing a display device according to an embodiment of the present invention.

FIGS. 24A to 24F are equivalent circuit diagrams illustrating protection circuits which are applied to a display device according to an embodiment of the present invention.

FIGS. 25A to 25D are views each illustrating a terminal portion of a display device according to an embodiment of the present invention.

FIGS. 26A to 26D are views each illustrating a terminal portion of a display device according to an embodiment of the present invention.

FIGS. 27A and 27B are a top view and a cross-sectional view, respectively, which illustrate an example of a liquid crystal display device according to an embodiment of the present invention.

FIGS. 28A and 28B are a top view and a cross-sectional view, respectively, which illustrate an example of a light-emitting display device according to an embodiment of the present invention.

FIGS. 29A to 29D are diagrams each illustrating an example of electronic devices to which an embodiment of the present invention is applied.

DETAILED DESCRIPTION OF THE INVENTION

Embodiments of the present invention will be described below with reference to the accompanying drawings. How-

ever, the present invention is not limited to the following description. It is easily understood by those skilled in the art that the modes and details of the present invention can be variously changed unless departing from the scope and the spirit of the present invention. Accordingly, the present invention should not be interpreted as being limited to the description of the embodiments and examples to be given below. Note that the same reference numerals are commonly used to denote the same components among different drawings in structures of the present invention described below.

Embodiment 1

In this Embodiment, a display device that is one embodiment of the present invention will be described with reference to a block diagram and the like.

FIG. 1A illustrates an example of a block diagram of an active matrix liquid crystal display device. The liquid crystal display device illustrated in FIG. 1A includes a pixel portion **101** including a plurality of pixels each provided with a display element, a scan line driver circuit **102** controlling a scan line connected to a gate electrode of each pixel, and a signal line driver circuit **103** controlling a video signal input to a selected pixel over a substrate **100**.

FIG. 1B illustrates an example of a block diagram of an active matrix light-emitting display device to which the present invention is applied. The light-emitting display device illustrated in FIG. 1B includes a pixel portion **111** including a plurality of pixels each provided with a display element, a first scan line driver circuit **112** and a second scan line driver circuit **113** which control a scan line connected to a gate electrode of each pixel, and a signal line driver circuit **114** controlling a video signal input to a selected pixel, over a substrate **110**. In the case where two TFTs, i.e., a switching TFT (thin film transistor, hereinafter, referred to as a TFT) and a current controlling TFT are placed in one pixel, in the light-emitting display device illustrated in FIG. 1B, a signal inputted to a first scan line connected to a gate electrode of the switching TFT is generated in the first scan line driver circuit **112** and a signal inputted to a second scan line connected to a gate electrode of the current controlling TFT is generated in the second scan line driver circuit **113**. Alternatively, the signal inputted to the first scan line and the signal inputted to the second scan line may be generated in one scan line driver circuit. Further alternatively, for example, a plurality of the first scan lines, which are used to control the operation of a switching element, may be provided in each pixel depending on the number of TFTs included in the switching element. In this case, all signals inputted to a plurality of the first scan lines may be generated in one scan line driver circuit or, by providing a plurality of scan line driver circuits, may be generated in their respective scan line driver circuits.

Note that, although a mode of forming the scan line driver circuit **102**, the first scan line driver circuit **112**, the second scan line driver circuit **113**, and the signal line driver circuits **103** and **114** in the display device is shown here, part of the scan line driver circuit **102**, the first scan line driver circuit **112**, or the second scan line driver circuit **113** may be mounted using a semiconductor device such as an IC. Further, part of the signal line driver circuits **103** and **114** may be mounted using a semiconductor device such as an IC.

FIG. 2 illustrates positional relations of signal input terminals, scan lines, signal lines, protection circuits including nonlinear elements, and a pixel portion, which are included in the display device. A scan line **123** and a signal line **124** are placed to cross each other and a pixel portion **127** is formed over a substrate **120** having an insulating surface. Note that

the pixel portion **127** corresponds to the pixel portion **101** in FIG. 1A or the pixel portion **111** in FIG. 1B.

The pixel portion **127** is formed by arranging a plurality of pixels **128** in a matrix. A pixel TFT **129** connected to the scan line **123** and the scan line **124**, a storage capacitor portion **130**, and a pixel electrode **131** are included in the pixel **128**.

As to the pixel structure described here, in the storage capacitor portion **130**, one electrode is connected to the pixel TFT **129** and the other electrode is connected to a capacitor line **132**. The pixel electrode **131** serves as one electrode which drives a display element (e.g. a liquid crystal element, a light-emitting element, a contrast medium (an electronic ink), or the like). The other electrode of the display element is connected to a common terminal **133**.

The protection circuits are provided between the pixel portion **127** and signal line input terminals **122**. Further, the protection circuits are provided between the scan line driver circuit and the pixel portion **127**. In this Embodiment, the plural protection circuits are provided to avoid a break of the pixel TFT **129** or the like due to a surge voltage which is applied to the scan line **123**, the signal line **124**, and a capacitor wiring **137** by static electricity or the like. Therefore, the protection circuits are formed such that charge is transferred to a common wiring when a surge voltage is applied.

In this Embodiment, an example of positions is shown, where the protection circuit **134** for the scan line **123**, the protection circuit **135** for the signal line **124**, and the protection circuit **136** for the capacitor wiring **137** are provided. However, the positions where the protection circuits are provided are not limited to the above-mentioned positions. Further, in the case where the scan line driver circuit is not mounted using a semiconductor device such as an IC, the protection circuit **134** is not necessarily provided on the scan line **123** side.

By the use of a TFT of the present invention for these circuits, there are advantages as below.

It is preferable that the pixel TFTs have high switching characteristics. By improving the switching characteristics of the pixel TFTs, the contrast ratio of a display device can be increased. In order to improve the switching characteristics, it is effective that on current is increased and off current is decreased. In the pixel TFT to which the present invention is applied, on current is large and off current is small, so that the switching characteristics thereof can be high, and therefore a thin film transistor with a high contrast ratio can be achieved.

The driver circuit is roughly divided into a logic circuit portion and a switch portion or a buffer portion. Preferably, a TFT provided in the logic circuit portion has a structure that can control a threshold voltage. On the other hand, a TFT provided in the switch portion or the buffer portion has preferably a large amount of on current. Accordingly, the threshold voltage of the TFT provided in the logic circuit portion can be controlled and on current of the TFT provided in the switch portion or in the buffer portion can be large. Moreover, the area occupied by the driver circuit can be reduced and the frame of the display device can be narrowed.

A protection circuit was one of the causes that prevent a frame of a display device from being narrowed because it is provided in the periphery of a pixel portion. However, as regards the display device described in this specification, the area of the protection circuits can be reduced; thus, inhibiting the narrow frame of the display device can be suppressed.

Embodiment 2

In this Embodiment, circuit diagrams of driver circuits of the display device described in Embodiment 1 will be described with reference to FIG. 3, FIG. 4, FIG. 5, and FIG. 6.

First, a shift register circuit included in the scan line driver circuit shown in Embodiment 1 will be described.

The shift register circuit illustrated in FIG. 3 includes a plurality of flip-flop circuits **201**, control signal lines **202**, **203**, **204**, **205**, and **206**, and reset lines **207**.

As in the shift register circuit illustrated in FIG. 3, a start pulse SSP is inputted to an input terminal IN of the flip-flop circuit **201** of the first stage through the control signal line **202**. An output signal terminal S_{out} of the flip-flop circuit **201** of the previous stage is connected to an input terminal IN of the flip-flop circuit **201** of the subsequent stages. A reset terminal RES of the N-th stage (N is a natural number) is connected to the output signal terminal S_{out} of the flip-flop circuit of the (N+3-th) stage through the reset line **207**. Provided that a first clock signal CLK1 is inputted to a clock terminal CLK of the flip-flop circuit **201** of the N-th stage through the control signal line **203**, a second clock signal CLK2 is inputted to a clock terminal CLK of the flip-flop circuit **201** of the (N+1-th) stage through the control signal line **204**. A third clock signal CLK3 is inputted to a clock terminal CLK of the flip-flop circuit **201** of the (N+2-th) stage through the control signal line **205**. A fourth clock signal CLK4 is inputted to a clock terminal CLK of the flip-flop circuit **201** of the (N+3-th) stage through the control signal line **206**. The first clock signal CLK1 is inputted to the clock terminal CLK of the flip-flop circuit **201** of the (N+4-th) stage through the control signal line **203**. Further, the flip-flop circuit **201** of the N-th stage outputs SR_{out} of the flip-flop circuit of the N-th stage from a gate output terminal G_{out} .

Note that, although the connection of the flip-flop circuits **201** to a power supply and a power supply line is not illustrated, a power supply potential V_{dd} and a power supply potential GND are supplied to each flip-flop circuit **201** through the power supply line.

Note that the power supply potential described in this specification corresponds to a potential difference in the case where a reference potential is set at 0 V; therefore, in some cases, the power supply potential is referred to as a power supply voltage.

Note that, in this specification, the phrase that "A and B are connected" includes the case where A and B are electrically connected in addition to the case where A and B are directly connected. Here, the phrase that "A and B are electrically connected" refers to the following situation: in the case where an object which causes some sort of electric action exists between A and B, A and B have substantially the same potential through the object. Specifically, electrical connection between A and B refers to the case where A and B can be regarded to have the same potential in consideration of the circuit operation, such as the case where A and B are connected through a switching element such as a TFT, and A and B have substantially the same potential by the conduction of the switching element, or the case where A and B are connected through a resistor, and a potential difference generated between the both edges of the resistor does not affect operation of a circuit that includes A and B.

Next, one mode of the flip-flop circuit **201** included in the shift register circuit illustrated in FIG. 3 is shown in FIG. 4. The flip-flop circuit **201** illustrated in FIG. 4 includes a logic circuit portion **211** and a switch portion **212**. The logic circuit portion **211** includes TFTs **213** to **218**. The switch portion **212** includes TFTs **219** to **222**. Note that the logic circuit portion **211** is a circuit for converting a signal outputted to the switch portion **212**, which is a next stage circuit in response to a signal inputted from the outside. In addition, the switch portion **212** is a circuit for switching on and off of a TFT serving as a switch in accordance with a signal inputted from the

outside and the logic circuit portion **211**, and for outputting a current corresponding to the size and the structure of the TFT.

In the flip-flop circuit **201**, the input terminal IN is connected to a gate terminal of the TFT **214** and a gate terminal of the TFT **217**. The reset terminal is connected to a gate terminal of the TFT **213**. The clock terminal CLK is connected to a first terminal of the TFT **219** and a first terminal of the TFT **221**. A power supply line to which a power supply potential V_{dd} is supplied is connected to a first terminal of the TFT **214** and a second terminal of the TFT **216**. A power supply line to which a power supply potential GND is supplied is connected to a second terminal of the TFT **213**, a second terminal of the TFT **215**, a second terminal of the TFT **217**, a second terminal of the TFT **218**, a second terminal of the TFT **220**, and a second terminal of the TFT **222**. A first terminal of the TFT **213**, a second terminal of the TFT **214**, a first terminal of the TFT **215**, a gate terminal of the TFT **218**, a gate terminal of the TFT **219**, and a gate terminal of the TFT **221** are connected to one another. A first terminal and a gate terminal of the TFT **216** are connected to a gate terminal of the TFT **215**, a first terminal of the TFT **217**, a first terminal of the TFT **218**, a gate terminal of the TFT **220**, and a gate terminal of the TFT **222**. The gate output terminal G_{out} is connected to a second terminal of the TFT **219** and a first terminal of the TFT **220**. An output signal terminal S_{out} is connected to a second terminal of the TFT **221** and a first terminal of the TFT **222**.

Note that, here, the case where all the TFTs **213** to **222** are n-type TFTs will be described. However, the TFTs **213** to **222** may be p-type TFTs.

A TFT is an element including at least three terminals, a gate, a drain, and a source. The TFT includes a channel formation region between a drain region and a source region, and current can flow through the drain region, the channel formation region, and the source region. Here, there is a case that the positions of the source and the drain are switched depending on a structure, operating conditions, or the like of the TFT, so it is difficult to define which is the source or the drain; therefore, the region that serves as a source and the region that serves as a drain are not referred to as a source and a drain, and for example, are expressed as a first terminal and a second terminal respectively. In this case, a terminal that serves as a gate is expressed as a gate terminal.

Next, an example of a layout diagram of the flip-flop circuit **201** illustrated in FIG. 4 is shown in FIG. 5.

The flip-flop circuit in FIG. 5 includes a power supply line **231** to which a power supply potential V_{dd} is supplied, a reset line **232**, the control signal line **203**, the control signal line **204**, the control signal line **205**, the control signal line **206**, a control signal line **233**, a power supply line **234** to which a power supply potential GND is supplied, the logic circuit portion **211**, and the switch portion **212**. The logic circuit portion **211** includes the TFTs **213** to **218**. The switch portion **212** includes the TFTs **219** to **222**. Further, FIG. 5 illustrates a wiring connected to the gate output terminal G_{out} and a wiring connected to the output signal terminal S_{out} .

In FIG. 5, a semiconductor layer **235**, a first wiring layer **236**, a second wiring layer **237**, a third wiring layer **238**, contact holes **239** are illustrated. Note that the first wiring layer **236** may be formed with a layer for forming the gate electrode, the second wiring layer **237** may be formed with a layer for forming the source electrode or the drain electrode of a TFT, and the third wiring layer **238** may be formed with a layer for forming the pixel electrode in the pixel portion. However, the present invention is not limited to this, and for

example, the third wiring layer **238** may be formed as a wiring layer that is different from the layer for forming the pixel electrode.

The connection relations of circuit elements in FIG. **5** are as described in FIG. **4**. Note that in FIG. **5**, the flip-flop circuit to which the first clock signal is inputted is illustrated and the connections of the flip-flop circuit and the control signal lines **204** to **206** are not illustrated.

In this Embodiment, an EDMOS circuit **223** can be formed by controlling the threshold voltage of the TFT **216** or the TFT **217** included in the logic circuit portion **211** in the layout diagram of the flip-flop circuit in FIG. **5**. Typically, one feature of the present invention is that the EDMOS circuit **223** in which the TFT **216** is a depletion type TFT and the TFT **217** is an enhancement type TFT is formed, and the TFTs **219** to **222** included in the switch portion **212** are formed using dual-gate type TFTs or depletion type TFTs.

A semiconductor layer including an impurity element serving as a donor is used for a channel formation region of the depletion type TFT **216**, and a semiconductor layer to which an impurity element serving as a donor is not added is used for a channel formation region of the enhancement type TFT **217**; thus, the EDMOS circuit **223** can be formed.

Alternatively, a semiconductor layer to which an impurity element serving as an acceptor is not added is used for the channel formation region of the depletion type TFT **216**, and a semiconductor layer including an impurity element serving as an acceptor is used for the channel formation region of the enhancement type TFT **217**; thus the EDMOS circuit **223** can be formed.

Further alternatively, by forming the depletion type TFT **216** or the enhancement type TFT **217** as a dual-gate TFT and controlling a potential of a back gate electrode, the depletion type TFT **216** or the enhancement type TFT **217** can be formed; thus, the EDMOS circuit **223** can be formed.

Accordingly, TFTs of the display device can be formed using only TFTs having one polarity such as n-type TFTs or p-type TFTs.

The TFT **216** in the logic circuit portion **211** is a TFT which allows current to flow depending on a power supply potential V_{dd} . By setting the TFT **216** as a dual-gate TFT or a depletion type TFT to increase the amount of flowing current, reduction in size of the TFT can be achieved without deteriorating performance of the TFT.

As to the TFTs included in the switch portion **212**, the amount of current flowing through the TFTs can be increased and switching of on and off can be conducted at high speed, so that the area occupied by the TFTs can be reduced without deteriorating performance of the TFTs. Accordingly, the area occupied by the circuit including the TFTs can also be reduced. Note that the TFTs **219** to **222** in the switch portion **212** may be formed as a dual-gate TFT in which the semiconductor layer **235** is interposed between the first wiring layer **236** and the third wiring layer **238** as illustrated in FIG. **5**.

In FIG. **5**, although an example of a dual-gate TFT having a structure in which the semiconductor layer **235** is interposed between the first wiring layer **236** and the third wiring layer **238**, which is connected to the first wiring layer **236** through contact holes **239** and has the same potential as the first wiring layer **236**, is shown, the present invention is not limited to this structure. For example, a structure in which another control signal line is provided with respect to the third wiring layer **238**, and the potential of the third wiring layer **238** is controlled independently from the first wiring layer **236** may be employed. The threshold voltage of the TFT is controlled by the third wiring layer **238**, and the amount of current flowing through the TFT is increased, whereby, the area occupied by

the TFT, moreover, the area occupied by the circuit including the TFTs can be reduced without deteriorating performance of the TFTs.

Note that as to the layout diagram of the flip-flop circuit of FIG. **5**, the shape of the channel formation regions of the TFTs **213** to **222** may be U-shape (reversed C shape, horseshoe shape). Further, although the size of each TFT is the same in FIG. **5**, the size of each TFT connected to the output signal terminal S_{out} or the gate output terminal G_{out} may be changed as appropriate in accordance with the level of the load of the next stage.

Next, operation of the shift register circuit illustrated in FIG. **3** is described with reference to a timing chart illustrated in FIG. **6**. FIG. **6** illustrates the start pulse SSP, the first clock signal CLK1 to the fourth clock signal CLK4 which are supplied to the control signal lines **202** to **206** respectively illustrated in FIG. **3**, and S_{out1} to S_{out5} which are outputted from the output signal terminals S_{out} of the flip-flop circuits of the first stage to the fifth stage respectively. Note that the same reference numerals of the elements used in FIG. **4** and FIG. **5** will be used in FIG. **6**.

FIG. **6** is a timing chart in the case where each TFT included in the flip-flop circuit is an n-type TFT. Further, the first clock signal CLK1 and the fourth clock signal CLK4 are, as illustrated, shifted by a quarter wavelength (a period sectioned by a dotted line).

First, in a period T1, a start pulse SSP of an H level is inputted to the flip-flop circuit of the first stage, and the logic circuit portion **211** turns on the TFT **219** and the TFT **221** in the switch portion and turns off the TFT **220** and the TFT **222** in the switch portion. At this time, the first clock signal CLK1 has an L level, and S_{out1} has an L level.

Note that, in the period T1, the flip-flop circuits of the second stage and the subsequent stages do not operate, and output an L level signal because signals are not inputted to the IN terminals of these flip-flop circuits. In this description, it is assumed that each flip-flop circuit of the shift register circuit in an initial state outputs an L level signal.

Next, in a period T2, the logic circuit portion **211** of the flip-flop circuit of the first stage controls the switch portion **212** in a manner similar to that in the period T1. In the period T2, the first clock signal CLK1 has an H level, and S_{out1} has an H level. Further, in the period T2, S_{out1} of an H level is inputted to the IN terminal of the flip-flop circuit of the second stage, and the logic circuit portion **211** turns on the TFT **219** and the TFT **221** and turns off the TFT **220** and the TFT **222** in the switch portion. At this time, the second clock signal CLK2 has an L level, and S_{out2} has an L level.

Note that, in the period T2, the flip-flop circuits of the third stage and the subsequent stages do not operate, and output an L level signal because signals are not inputted to the IN terminals of these flip-flop circuits.

Next, in the period T3, the logic circuit portion **211** of the flip-flop circuit of the first stage controls the switch portion **212** in order to keep the state of the period T2; therefore, in the period T3, the first clock signal CLK1 has an H level, and S_{out1} has an H level. Further, in the period T3, the logic circuit portion **211** of the flip-flop circuit of the second stage controls the switch portion **212** in a manner similar to that in the period T2. In the period T3, the second clock signal CLK2 is an H level, and S_{out2} is an H level. Further, in the period T3, S_{out2} of an H level is inputted to the IN terminal of the flip-flop circuit of the third stage, and the logic circuit portion **211** turns on the TFT **219** and the TFT **221** and turns off the TFT **220** and the TFT **222**. At this time, the third clock signal CLK3 has an L level, and S_{out3} has an L level.

11

Note that, in the period T3, the flip-flop circuits of the fourth stage and the subsequent stages do not operate, and output an L level signal because signals are not inputted to the IN terminals of these flip-flop circuits.

Next, in the period T4, the first clock signal CLK1 has an L level, and S_{out1} has an L level. In the period T4, the logic circuit portion 211 of the flip-flop circuit of the second stage controls the switch portion 212 in order to keep the state of the period T3; therefore, in the period T4, the second clock signal CLK2 has an H level, and S_{out2} has an H level. Further, in the period T4, the logic circuit portion 211 of the flip-flop circuit of the third stage controls the switch portion 212 in a manner similar to that in the period T3. In the period T4, the third clock signal CLK3 has an H level, and S_{out3} has an H level. Further, in the period T4, S_{out3} of an H level is inputted to the IN terminal of the flip-flop circuit of the fourth stage, the logic circuit portion 211 turns on the TFT 219 and the TFT 221 in the switch portion 212 and turns off the TFT 220 and the TFT 222 in the switch portion 212. At this time, the fourth clock signal CLK4 has an L level, and S_{out4} has an L level.

Note that, in the period T4, the flip-flop circuits of the fifth stage and the subsequent stages do not operate, and output an L level signal because signals are not inputted to the IN terminals of these flip-flop circuits.

Next, in the period T5, the logic circuit portion 211 of the flip-flop circuit of the first stage controls the switch portion 212 in order to keep the state of the period T4; therefore, in the period T5, the first clock signal CLK1 has an L level, and S_{out1} has an L level. Further, in the period T5, the logic circuit portion 211 of the flip-flop circuit of the second stage controls the switch portion 212 in a manner similar to that in the period T4. In the period T5, the second clock signal CLK2 has an L level, and S_{out2} has an L level. Further, in the period T5, the logic circuit portion 211 of the flip-flop circuit of the third stage controls the switch portion 212 in order to keep the state of the period T4; therefore, in the period T5, the third clock signal CLK3 has an H level, and S_{out3} has an H level. Further, in the period T5, the logic circuit portion 211 of the flip-flop circuit of the fourth stage controls the switch portion 212 in a manner similar to that in the period T4. In the period T5, the fourth clock signal CLK4 has an H level, and S_{out4} has an H level. The relation of wirings of the flip-flop circuit of the fifth stage and the subsequent stages is the same as those of the flip-flop circuit of the first stage to the fourth stage, and the timing at which a signal is inputted to the flip-flop circuit of the fifth stage and the subsequent stages is also the same as that of the first stage to the fourth stage, so the description is omitted.

As shown in the shift register circuit illustrated in FIG. 3, S_{out4} also serves as the reset signal of the flip-flop circuit of the first stage. In the period T5, S_{out4} has an H level and this signal is inputted to a reset terminal RES of the flip-flop circuit of the first stage. The input of the reset signal turns off the TFT 219 and the TFT 221 in the switch portion 212 and turns on the TFT 220 and the TFT 222 in the switch portion 212. Then, S_{out1} of the flip-flop circuit of the first stage outputs an L level signal until a next start pulse SSP is inputted.

By the aforementioned operation, in the flip-flop circuits of the second stage and the subsequent stages, a reset in the logic circuit portion is conducted in accordance with a reset signal outputted from the flip-flop circuit of the next stage, and the shift register circuit outputs signals which are shifted by a quarter wavelength of the clock circuit such as S_{out1} to S_{out5} .

Further, as a flip-flop circuit, an EDMOS circuit in which an enhancement type TFT and a depletion type TFT are combined is provided in the logic circuit portion 211, and a

12

dual-gate TFT is provided in the switch portion 212, so that the amount of current flowing through the TFTs included in the logic circuit portion 211 can be increased, and the area occupied by TFTs, moreover, the area occupied by the circuit including the TFTs can be reduced without deteriorating performance of the TFTs. Furthermore, as to the TFTs included in the switch portion 212, the amount of current flowing through the TFTs can be increased and switching of on and off can be conducted at high speed, so that the area occupied by the TFTs, moreover, the area occupied by the circuit including the TFTs can be reduced without deteriorating performance of the TFTs. Accordingly, the frame of the display device can be narrowed and the display device can be downsized and have higher performance.

Further, a latch circuit, a level shifter circuit, or the like can be provided in the signal line driver circuit described in Embodiment 1. A buffer portion is provided in the last stage sending a signal from the signal line driver circuit to the pixel portion, and a signal of which the amount of current is amplified is sent from the signal line driver circuit to the pixel portion. By providing a TFT through which a large amount of on current flows, typically a dual-gate TFT or a depletion type TFT in the buffer portion, the area of the TFT can be reduced and the area occupied by the signal line driver circuit can be reduced. Accordingly, the frame of the display device can be narrowed and the display device can be downsized and have higher performance. Note that a shift register circuit, which is part of the signal line driver circuit, is preferably mounted on the display device using an IC, or the like because the shift register circuit is required to operate at high speed.

Embodiment 3

In this Embodiment, as to the display device described in Embodiments 1 and 2, structures of the logic circuit portion, the switch portion, and the thin film transistor in the pixel portion will be described. As for a thin film transistor used for a display device, an n-type transistor has higher carrier mobility than a p-type transistor. It is preferable that all thin film transistors formed over the same substrate have the same polarity because the number of manufacturing steps can be reduced. In this Embodiment, an n-type thin film transistor will be described.

FIG. 7 and FIG. 8A each illustrate a cross-sectional view of one mode (structure 1) of a logic circuit portion 391, a switch portion 393, and a pixel portion 395 in the display device according to this Embodiment.

An EDMOS circuit is used for the logic circuit portion 391 in the display device illustrated in FIG. 7. One of a depletion type TFT and an enhancement type TFT in the EDMOS circuit is a dual-gate TFT 300a including a gate electrode 303 and a back gate electrode 373. The other of a depletion type TFT and an enhancement type TFT in the EDMOS circuit is a TFT 300b. Note that C-D in the cross-sectional view of the logic circuit portion 391 illustrated in FIG. 7 and C-E in the cross-sectional view of the logic circuit portion 391 illustrated in FIG. 8A correspond to C-D and C-E in a top view of FIG. 8B respectively.

In the switch portion 393 in the display device illustrated in FIG. 7, a dual-gate TFT 300c including a gate electrode 305 and a back gate electrode 374 is formed.

A switching element in the pixel portion 395 in the display device illustrated in FIG. 7 is a TFT 300d. Further, a capacitor 300e is formed by including a second gate insulating layer 379, a capacitor wiring 353, and a wiring 375.

The TFT 300a includes, over a substrate 301, the gate electrode 303, a first semiconductor layer 333a, a second

13

semiconductor layer **333b**, a third semiconductor layer **363**, a first gate insulating layer **309** provided between the gate electrode **303** and the first semiconductor layer **333a**, impurity semiconductor layers **355** and **356** which are in contact with the third semiconductor layer **363** and function as a source region and a drain region, and wirings **346** and **347** which are in contact with the impurity semiconductor layers. The second gate insulating layer **379** is formed, which covers the first semiconductor layer **333a**, the second semiconductor layer **333b**, the third semiconductor layer **363**, the first gate insulating layer **309**, the impurity semiconductor layers **355** and **356**, and the wirings **346** and **347** which are in contact with the impurity semiconductor layers. The back gate electrode **373** is provided to face the gate electrode **303** with the second gate insulating layer **379** interposed therebetween.

The TFT **300b** includes, over the substrate **301**, the gate electrode **304**, the first semiconductor layer **333a**, the second semiconductor layer **333b**, the third semiconductor layer **363**, the first gate insulating layer **309** provided between the gate electrode **304** and the first semiconductor layer **333a**, impurity semiconductor layers **356** and **357** which are in contact with the third semiconductor layer **363** and function as a source region and a drain region, and wirings **347** and **348** which are in contact with the impurity semiconductor layers.

As illustrated in FIG. 8A, the gate electrode **303** of the TFT **300a** and the wiring **347** of the TFT **300a** and the TFT **300b** are connected with a wiring **384**, which is formed over an insulating layer **381** at the same time as a pixel electrode **383** is formed.

The TFT **300c** includes, over the substrate **301**, the gate electrode **305**, the first semiconductor layer **334a**, the second semiconductor layer **334b**, the third semiconductor layer **364**, the first gate insulating layer **309** provided between the gate electrode **305** and the first semiconductor layer **334a**, impurity semiconductor layers **358** and **359** which are in contact with the third semiconductor layer **364** and function as a source region and a drain region, and wirings **349** and **350** which are in contact with the impurity semiconductor layers. The second gate insulating layer **379** is formed, which covers the first semiconductor layer **334a**, the second semiconductor layer **334b**, the third semiconductor layer **364**, the first gate insulating layer **309**, the impurity semiconductor layers **358** and **359**, the wirings **349** and **350**. The back gate electrode **374** is provided to face the gate electrode **305** with the second gate insulating layer **379** interposed therebetween.

The TFT **300d** includes, over the substrate **301**, the gate electrode **306**, the first semiconductor layer **335a**, the second semiconductor layer **335b**, the third semiconductor layer **365**, the first gate insulating layer **309** provided between the gate electrode **306** and the first semiconductor layer **335a**, impurity semiconductor layers **360** and **361** which are in contact with the third semiconductor layer **365** function as a source region and a drain region, and wirings **351** and **352** which are in contact with the impurity semiconductor layers.

Further, the capacitor **300e** is formed by including the second gate insulating layer **379**, the capacitor wiring **353**, and the wiring **375**.

As for the substrate **301**, a plastic substrate with heat resistance that can resist a process temperature in this manufacturing step or the like can be used in addition to a glass substrate and a ceramic substrate. In the case where the substrate does not need a light-transmitting property, a metal substrate such as a stainless steel alloy, on the surface on which an insulating layer is provided, may be used. As for a glass substrate, for example, a non-alkali glass substrate formed using barium borosilicate glass, aluminoborosilicate glass, aluminosilicate glass, or the like may be used. Further,

14

as for the substrate **301**, a glass substrate with any of the following sizes can be used: the 3rd generation (550 mm×650 mm), the 3.5th generation (600 mm×720 mm or 620 mm×750 mm), the 4th generation (680×880 mm or 730 mm×920 mm), the 5th generation (1100 mm×1300 mm), the 6th generation (1500 mm×1850 mm), the 7th generation (1870 mm×2200 mm), the 8th generation (2200 mm×2400 mm), the 9th generation (2400 mm×2800 mm or 2450 mm×3050 mm), or the 10th generation (2950 mm×3400 mm).

The gate electrodes **303** to **306** and the capacitor wiring **307** can be formed with a single layer or a stacked layer using a metal material such as molybdenum, titanium, chromium, tantalum, tungsten, aluminum, copper, neodymium, or scandium, or an alloy material including any of these materials as a main component. Alternatively, a semiconductor layer typified by polycrystalline silicon doped with an impurity element such as phosphorus, or an AgPdCu alloy may be used.

For example, as for a two-layer structure of the gate electrodes **303** to **306** and the capacitor wiring **307**, a two-layer structure in which a molybdenum layer is stacked over an aluminum layer, a two-layer structure in which a molybdenum layer is stacked over a copper layer, a two-layer structure in which a titanium nitride layer or a tantalum nitride is stacked over a copper layer, or a two-layer structure in which a titanium nitride layer and a molybdenum layer are stacked is preferable. As for a three-layer structure of the gate electrodes **303** to **306** and the capacitor wiring **307**, a stacked-layer structure in which a tungsten layer or a tungsten nitride layer, a layer of an alloy of aluminum and silicon or a layer of an alloy of aluminum and titanium, and a titanium nitride layer or a titanium layer are stacked is preferable. When a metal layer that functions as a barrier layer is stacked over a layer with low electric resistance, electric resistance can be low and diffusion of metal elements from the metal layer into a semiconductor layer can be prevented.

The first gate insulating layer **309** can be formed with a single layer or a stacked layer using a silicon oxide layer, a silicon nitride layer, a silicon oxynitride layer, or a silicon nitride oxide layer by a CVD method, a sputtering method, or the like. By use of silicon oxide or silicon oxynitride to form the first gate insulating layer **309**, in the case where the first semiconductor layers **333a** to **335a** are microcrystalline semiconductor layers, fluctuation in the threshold voltage of the thin film transistors can be reduced.

Note that, in this specification, silicon oxynitride means silicon that includes more oxygen than nitrogen. Preferably, in the case where measurements are performed using Rutherford backscattering spectrometry (RBS) and hydrogen forward scattering (HFS), silicon oxynitride includes oxygen, nitrogen, silicon, and hydrogen at percentages ranging from 50 at. % to 70 at. %, 0.5 at. % to 15 at. %, 25 at. % to 35 at. %, and 0.1 at. % to 10 at. %, respectively. Further, silicon nitride oxide means silicon that includes more nitrogen than oxygen. Preferably, in the case where measurements are performed using RBS and HFS, silicon nitride oxide includes oxygen, nitrogen, silicon, and hydrogen at percentages ranging from 5 at. % to 30 at. %, 20 at. % to 55 at. %, 25 at. % to 35 at. %, and 10 at. % to 30 at. %, respectively. Note that percentages of nitrogen, oxygen, silicon, and hydrogen fall within the ranges given above, where the total number of atoms contained in the silicon oxynitride or the silicon nitride oxide is defined as 100 at. %.

The first semiconductor layers **333a** to **336a** are formed using a microcrystalline semiconductor layer. A microcrystalline semiconductor means a semiconductor having an intermediate structure between amorphous and crystalline structures (including a single crystal and a polycrystal). A

microcrystalline semiconductor is a semiconductor having a third state that is stable in terms of free energy and a crystalline semiconductor having short-range order and lattice distortion, in which column-like crystals or needle-like crystals having a grain size of 2 nm to 200 nm inclusive, preferably 10 nm to 80 nm inclusive, more preferably 20 nm to 50 nm inclusive, have grown in a direction normal to the substrate surface. Accordingly, there is a case where crystal grain boundaries are formed at the interface of column-like crystals or needle-like crystals.

The Raman spectrum of a microcrystalline silicon, which is a typical example of a microcrystalline semiconductor, is shifted to a lower wavenumber side than 520 cm^{-1} that represents single crystal silicon. That is, the peak of the Raman spectrum of a microcrystalline silicon exists between 520 cm^{-1} and 480 cm^{-1} which represent that of single crystal silicon and that of amorphous silicon, respectively. A microcrystalline semiconductor contains hydrogen or halogen of at least 1 at. % to terminate dangling bonds. Moreover, a rare gas element such as helium, argon, krypton, or neon may be contained to further promote lattice distortion, so that stability is enhanced and a favorable microcrystalline semiconductor can be obtained. Such a microcrystalline semiconductor is disclosed in, for example, U.S. Pat. No. 4,409,134.

It is preferable that the concentration of oxygen and nitrogen contained in the first semiconductor layers **333a** to **336a** measured by secondary ion mass spectrometry is less than 1×10^{18} atoms/cm³ because the crystallinity of the first semiconductor layers **333a** to **336a** can be improved.

The third semiconductor layers **363** to **366** are formed using an amorphous semiconductor layer, an amorphous semiconductor layer including halogen, or an amorphous semiconductor layer including nitrogen. Nitrogen of the amorphous semiconductor layer including nitrogen may exist, for example, as an NH group or an NH₂ group. The amorphous semiconductor layer is formed using amorphous silicon.

In the case where the third semiconductor layers **363** to **365** are formed with an amorphous semiconductor layer including nitrogen, a band tail slope in a band gap is steeper, the band gap becomes wide, and a tunnel current does not easily flow as compared to a conventional amorphous semiconductor layer. Accordingly, off current of the thin film transistor can be reduced.

In FIGS. 9A and 9B, enlarged views of a portion between the first gate insulating layer **309** and the impurity semiconductor layers **355** to **361** which function as a source region and a drain region of FIG. 7 are illustrated.

As FIG. 9A illustrates, the second semiconductor layers **333b** to **335b** are provided between the first semiconductor layers **333a** to **335a** and the third semiconductor layers **363** to **365**. The second semiconductor layers **333b** to **335b** include microcrystalline semiconductor regions **367** and amorphous semiconductor regions **368** filling the space except the microcrystalline semiconductor regions **367**. Specifically, the second semiconductor layers **333b** to **335b** are formed including the microcrystalline semiconductor regions **367**, which grow with a convex shape from the first semiconductor layers **333a** to **335a**, and the amorphous semiconductor regions **368** which are formed of the same material as that of the third semiconductor layers **363** to **365**. Further, the second semiconductor layers **333b** to **335b** may include using an amorphous semiconductor region including halogen or an amorphous semiconductor region including nitrogen instead of the amorphous semiconductor region **368**.

The off current of the thin film transistor can be reduced by forming the third semiconductor layers **363** to **365** using an

amorphous semiconductor layer, an amorphous semiconductor layer including halogen, an amorphous semiconductor layer including nitrogen, or an amorphous semiconductor layer including an NH group each having a low conductivity and a high resistivity. As to the second semiconductor layers **333b** to **335b**, because the second semiconductor layers **333b** to **335b** include the conical or pyramidal microcrystalline semiconductor regions **367**, resistance of the vertical direction (the film thickness direction) in the case where the thin film transistor is in on-state and voltage is applied to the wiring thereof, that is, resistance between the semiconductor layer and the source region or the drain region, can be lowered, and on current of the thin film transistor can be increased.

As illustrated in FIG. 9B, a structure that the second semiconductor layers **333b** to **335b** are provided between the first semiconductor layers **333a** to **335a** and the impurity semiconductor layers **355** to **361** may be employed. That is, the third semiconductor layers are not formed between the second semiconductor layers **333b** to **335b** and the impurity semiconductor layers **355** to **361**. The second semiconductor layers **333b** to **335b** include the microcrystalline semiconductor regions **367**, and the amorphous semiconductor regions **368** filling the space except the microcrystalline semiconductor regions **367**. Specifically, the second semiconductor layers **333b** to **335b** are formed using the microcrystalline semiconductor regions **367** that grow with a convex shape from the first semiconductor layers **333a** to **335a** and the amorphous semiconductor region **368**. In the structure illustrated in FIG. 9B, it is preferable that the proportion of the microcrystalline semiconductor regions **367** as compared to the amorphous semiconductor regions **368** is low. Further, it is preferable that the proportion of the microcrystalline semiconductor regions **367** is low in a region between each pair of the impurity semiconductor layers **355**, **356**, **358**, and **360** and the impurity semiconductor layers **356**, **357**, **359**, and **361**, that is, in a region in which carriers flow. Accordingly, off current of the thin film transistor can be reduced. As to the second semiconductor layers **333b** to **335b**, resistance of the vertical direction (the film thickness direction) in the case where the thin film transistor is in on-state and voltage is applied to the wiring thereof, that is, resistance between the semiconductor layer and the source region or the drain region, can be lowered, and on current of the thin film transistor can be increased.

The microcrystalline semiconductor region **367** is a crystal grain having a convex shape whose top gets narrower from the first gate insulating layer **309** toward the third semiconductor layers **363** to **365**. Alternatively, the microcrystalline semiconductor region **367** may be a crystal grain having a convex shape whose top gets wider from the first gate insulating layer **309** toward the third semiconductor layers **363** to **365**.

In the second semiconductor layers **333b** to **335b**, in the case where the microcrystalline semiconductor region **367** is a crystal grain having a convex shape whose top gets narrower from the first gate insulating layer **309** toward the third semiconductor layers **363** to **365**, the proportion of the microcrystalline semiconductor regions **367** on the first semiconductor layers **333a** to **335a** side is higher than that of the third semiconductor layers **363** to **365** side. This is because the microcrystalline semiconductor region **367** grows from the surface of the first semiconductor layers **333a** to **335a** in the film thickness direction, and in the case where the flow rate of hydrogen to silane in the source gas is low or the concentration of the source gas including nitrogen is high, the growth of the crystal grains of the microcrystalline semiconductor

regions **367** is suppressed, the shape thereof becomes conical or pyramidal, and gradually only amorphous semiconductor regions are deposited.

The second semiconductor layers **333b** to **335b** preferably include nitrogen. This is because defects are reduced in the case where nitrogen, typically an NH group or an NH₂ group, is combined with dangling bonds of silicon atoms in the interface between the crystal grains included in the microcrystalline semiconductor region **367**, and in the interface between the microcrystalline semiconductor region **367** and the amorphous semiconductor region **368**. Accordingly, the nitrogen concentration of the second semiconductor layers **333b** to **335b** is set at greater than or equal to 1×10^{19} atoms/cm³ and less than or equal to 1×10^{21} atoms/cm³, preferably, greater than or equal to 1×10^{20} atoms/cm³ and less than or equal to 1×10^{21} atoms/cm³, and therefore, the dangling bonds of silicon atoms can be easily combined with nitrogen, preferably an NH group, so that a carrier can also flow easily. Alternatively, the dangling bonds of the semiconductor atoms in the aforementioned interface are terminated with the NH₂ group, so that the defect level is disappeared. As a result, resistances of the vertical direction (the film thickness direction) are reduced in the case where the thin film transistor is in on-state and voltage is applied between the source electrode and drain electrode. That is, the field effect mobility and on current of the thin film transistor are increased.

By reducing the concentration of oxygen of the second semiconductor layers **333b** to **335b**, bonding inhibiting carrier transfer in the interface between the microcrystalline semiconductor region **367** and the amorphous semiconductor region **368** or the interface between the crystal grains, can be reduced.

Note that, hereupon, the first semiconductor layers **333a** to **335a** refer to the regions of which thicknesses are approximately the same. The interface between the first semiconductor layers **333a** to **335a** and the second semiconductor layers **333b** to **335b** refers to a region obtained by extending the nearest region to the first gate insulating layer **309** in flat portion of the interface between the microcrystalline semiconductor region **367** and the amorphous semiconductor region **368**.

The off current of the TFTs can be suppressed by setting the total thickness of the first semiconductor layers **333a** to **335a** and the second semiconductor layers **333b** to **335b**, that is, the length from the interface with the first gate insulating layer **309** to the top of the projection of the second semiconductor layers **333b** to **335b**, to be greater than or equal to 3 nm and less than or equal to 80 nm, preferably, greater than or equal to 5 nm and less than or equal to 30 nm.

The impurity semiconductor layers **355** to **362** are formed with amorphous silicon to which phosphorus is added, microcrystalline silicon to which phosphorus is added, or the like. Note that, in the case of forming a p-type thin film transistor is formed as a thin film transistor, the impurity semiconductor layers **355** to **362** are formed with microcrystalline silicon to which boron is added, amorphous silicon to which boron is added, or the like. Note that, in the case where the second semiconductor layers **333b** to **336b** or the third semiconductor layers **363** to **366** have an ohmic contact with wirings **346** to **352** and the capacitor wiring **353**, the impurity semiconductor layers **355** to **362** are not necessarily formed.

Further, in the case where the impurity semiconductor layers **355** to **362** are formed with microcrystalline silicon to which phosphorus is added or microcrystalline silicon to which boron is added, a microcrystalline semiconductor layer, typically a microcrystalline semiconductor layer, is formed between the second semiconductor layers **333b** to

336b or the third semiconductor layers **363** to **366** and the impurity semiconductor layers **355** to **362**, so that characteristics of the interface can be improved. As this result, resistance generated in the interface between the impurity semiconductor layers **355** to **362** and the second semiconductor layers **333b** to **336b** or the third semiconductor layers **363** to **366** can be reduced. Accordingly, the amount of current flowing in a source region, a semiconductor layer, and a drain region of the thin film transistor is increased, and on current and a field effect mobility of the thin film transistor can be increased.

The wirings **346** to **352** and the capacitor wiring **353** can be formed with a single layer structure or a stacked-layer structure of aluminum, copper, titanium, neodymium, scandium, molybdenum, chromium, tantalum, tungsten, or the like. Alternatively, an aluminum alloy to which an element to prevent a hillock is added (e.g., an Al—Nd alloy which can be used for the gate electrodes **303** to **306** and the capacitor wiring **307**) may be used. Further alternatively, crystalline silicon to which an impurity element serving as a donor is added may be used. Further, the wirings **346** to **352** and the capacitor wiring **353** may have a stacked-layer structure obtained as follows; a layer, which is in contact with the crystalline silicon to which an impurity element serving as a donor is added, is formed using titanium, tantalum, molybdenum, tungsten, or nitride of any of these elements, and then aluminum or an aluminum alloy is formed thereover. Furthermore, a stacked layer structure may be employed in which upper and lower surfaces of aluminum or an aluminum alloy may each be covered with titanium, tantalum, molybdenum, tungsten, or nitride thereof.

The second gate insulating layer **379** can be formed in a manner similar to the first gate insulating layer **309**.

The back gate electrodes **373** and **374** and the wiring **375** can be formed in a manner similar to the wirings **346** to **352** and the capacitor wiring **353**.

The insulating layer **381** can be formed using an inorganic insulating layer or an organic resin layer. Examples of the inorganic insulating layer include silicon oxide, silicon oxynitride, silicon nitride oxide, carbon typified by DLC (diamond-like carbon). Examples of the organic resin layer include acrylic, epoxy, polyimide, polyamide, polyvinylphenol, benzocyclobutene. Alternatively, siloxane polymer can be used.

The pixel electrode **383** and the wiring **384** can be formed using indium oxide containing tungsten oxide, indium zinc oxide containing tungsten oxide, indium oxide containing titanium oxide, indium tin oxide containing titanium oxide, indium tin oxide, indium zinc oxide, indium tin oxide to which silicon oxide is added, or the like.

Alternatively, the pixel electrode **383** and the wiring **384** can be formed using a conductive composition containing a conductive high molecule (also referred to as a conductive polymer) having a light-transmitting property. As to the wiring **384** and the pixel electrode **383**, it is preferable that the sheet resistance be less than or equal to 10000Ω/square and the light transmittance is greater than or equal to 70% at a wavelength of 550 nm. Further, the resistivity of the conductive high molecule contained in the conductive composition is preferably less than or equal to 0.1Ω·cm.

As the conductive high molecule, a so-called π electron conjugated conductive high molecule can be used. For example, polyaniline or a derivative thereof, polypyrrole or a derivative thereof, polythiophene or a derivative thereof, copolymer of two or more kinds of those materials are given.

In a dual-gate TFT, the threshold voltage can be controlled by changing the potentials of the gate electrode **303** and the

19

back gate electrode **373**. In the logic circuit portion **391**, one of a depletion type TFT and an enhancement type TFT is set to be the dual-gate TFT **300a**, and the other of the depletion type TFT and the enhancement type TFT is set to be the TFT **300b** illustrated in FIG. 7; thus the EDMOS circuit can be formed.

Further, when a dual-gate TFT is employed, there are two channels where carriers flow, that is, around an interface with the first gate insulating layer **309** and around an interface with the second gate insulating layer **379**, so that the amount of carrier transfer is increased and on current of the thin film transistor can be increased. Accordingly, the dual-gate TFT **300c** which can increase the on current is formed in the switch portion **393**, so that the area of the TFT can be reduced and the area of the driver circuit of the display device can be narrowed.

Next, FIG. 10 and FIGS. 11A and 11B each illustrate a cross-sectional view of one mode (structure 2) of the logic circuit portion **391**, the switch portion **393**, and the pixel portion **395** in the display device according to this Embodiment.

FIG. 10 illustrates an EDMOS circuit of the logic circuit portion **391** in the display device. As a depletion type TFT **401a** in the EDMOS circuit, a TFT including a first semiconductor layer in which an impurity element imparting one conductivity type is added to the channel formation region is formed. An enhancement type TFT **401b** is also formed. Note that C-D in a cross-sectional view of the logic circuit portion **391** illustrated in FIG. 10 and C-E in a cross-sectional view of the logic circuit portion **391** illustrated in FIG. 11A correspond to C-D and C-E in a top view of FIG. 11B respectively.

In the switch portion **393** in the display device illustrated in FIG. 10, a TFT including the first semiconductor layer in which an impurity element imparting one conductivity type is added to the channel formation region, hereupon, a depletion type TFT **401c** including the first semiconductor layer to which an impurity element serving as a donor is added is formed.

The TFT **401a** includes, over a substrate **301**, a gate electrode **303**, a first semiconductor layer **427a** to which an impurity element imparting one conductivity type is added, a second semiconductor layer **427b**, a third semiconductor layer **469**, a first gate insulating layer **309** provided between the gate electrode **303** and the first semiconductor layer **427a** to which an impurity element imparting one conductivity type is added, impurity semiconductor layers **459** and **460** which are in contact with the third semiconductor layer **469** and function as a source region and a drain region, and wirings **451** and **452** which are in contact with the impurity semiconductor layers **459** and **460** respectively.

The TFT **401b** includes, over the substrate **301**, a gate electrode **304**, a first semiconductor layer **454a**, a second semiconductor layer **454b**, a third semiconductor layer **470**, the first gate insulating layer **309** provided between the gate electrode **304** and the first semiconductor layer **454a**, impurity semiconductor layers **461** and **462** which are in contact with the third semiconductor layer **470** and function as a source region and a drain region, and wirings **452** and **453** which are in contact with the impurity semiconductor layers **461** and **462** respectively.

As FIG. 11A illustrates, the gate electrode **303** of the TFT **401a** and the wiring **452** of the TFT **401a** and the TFT **401b** are connected with the wiring **384**, which is formed over the insulating layer **381** at the same time as the pixel electrode **383** is formed.

The TFT **401c** includes, over the substrate **301**, a gate electrode **305**, a first semiconductor layer **428a** to which an

20

impurity element imparting one conductivity type is added, a second semiconductor layer **428b**, a third semiconductor layer **471**, the first gate insulating layer **309** provided between the gate electrode **305** and the first semiconductor layer **428a**, impurity semiconductor layers **463** and **464** which are in contact with the third semiconductor layer **471** and function as a source region and a drain region, and wirings **454** and **455** which are in contact with the impurity semiconductor layers **463** and **464**.

The TFT **401d** includes, over the substrate **301**, a gate electrode **306**, a first semiconductor layer **455a**, a second semiconductor layer **455b**, a third semiconductor layer **472**, the first gate insulating layer **309** provided between the gate electrode **306** and the first semiconductor layer **455a**, impurity semiconductor layers **465** and **466** which are in contact with the third semiconductor layer **472** and function as a source region and a drain region, and wirings **456** and **457** which are in contact with the impurity semiconductor layers **465** and **466**.

As to the first semiconductor layers **427a** and **428a** to which an impurity element imparting one conductivity type is added, hereupon, an impurity element serving as a donor is added. As the impurity element serving as a donor, an element belonging to Group 15 of the periodic table, typically, phosphorus, arsenic, antimony, or the like is used. Hereupon, as the first semiconductor layer **427a** to which an impurity element imparting one conductivity type is added, a microcrystalline semiconductor layer to which phosphorus, which is an impurity element serving as a donor, is added is formed.

The first semiconductor layers **454a** to **456a** can be formed in a manner similar to the first semiconductor layers **333a** to **336a** shown in the aforementioned (structure 1).

The second semiconductor layers **427b**, **428b**, and **454b** to **456b** can be formed in a manner similar to the second semiconductor layers **333b** to **336b** shown in the aforementioned (structure 1).

The third semiconductor layers **469** to **473** can be formed in a manner similar to the third semiconductor layers **363** to **366** shown in the aforementioned (structure 1).

Note that, although a structure is shown here, in which the third semiconductor layers **469** to **473** are provided between the second semiconductor layers **427b**, **428b**, and **454b** to **456b** and the impurity semiconductor layers **459** to **467** as illustrated in FIG. 9A, the third semiconductor layers **469** to **473** are not necessarily formed as illustrated in FIG. 9B.

The impurity semiconductor layers **459** to **467** can be formed in a manner similar to the impurity semiconductor layers **355** to **362** shown in the aforementioned (structure 1).

The wirings **451** to **458** can be formed in a manner similar to the wirings **346** to **353** shown in the aforementioned (structure 1).

Note that although a TFT including the first semiconductor layer in which an impurity element imparting one conductivity type is added to the channel formation region is used as the depletion type TFT **401a** of an EDMOS circuit in FIG. 10, a TFT with a structure described as follows may be employed: the channel formation region of the depletion type TFT **401a** is formed in a manner similar to the first semiconductor layer **454a** of the TFT **401b**, and the enhancement type TFT **401b** includes the first semiconductor layer in which an impurity element imparting one conductivity type, typically an impurity element serving as an acceptor, is added to the channel formation region. As the impurity element serving as an acceptor, an element belonging to Group 13 of the periodic table, typically, boron, or the like is used.

Hereupon, in the logic circuit portion **391**, the depletion type TFT or the enhancement type TFT includes a semicon-

21

ductor layer in which an impurity element imparting one conductivity type is added to the channel formation region; therefore, an EDMOS circuit can be formed.

Further, a depletion type TFT can increase on current because the threshold voltage of a depletion type TFT is shifted to negative side. A depletion type TFT, which can increase on current, is formed for a TFT in the switch portion 393, so that the area of the TFT can be reduced and the area of the driver circuit in the display device can be narrowed.

Next, FIG. 12 and FIGS. 13A and 13B each illustrate a cross-sectional view of one mode (structure 3) of the logic circuit portion 391, the switch portion 393, and the pixel portion 395 in the display device according to this Embodiment.

FIG. 12 illustrates an EDMOS circuit of the logic circuit portion 391 in the display device. As a depletion type TFT 401a of the EDMOS circuit, as shown in the aforementioned (structure 2), the TFT including the first semiconductor layer in which an impurity element imparting one conductivity type is added to the channel formation region is formed. The TFT 401b shown in (structure 2) is formed as an enhancement type TFT 401b. Note that C-D in a cross-sectional view of the logic circuit portion 391 illustrated in FIG. 12 and C-E in a cross-sectional view of the logic circuit portion 391 illustrated in FIG. 13A correspond to C-D and C-E in a top view FIG. 13B respectively.

In the switch portion 393 in the display device illustrated in FIG. 12, a dual-gate TFT 403c including the gate electrode 305 and a back gate electrode 482 is formed.

A switching element of a pixel in the pixel portion 395 in the display device illustrated in FIG. 12 is formed using a TFT 401d. Further, a capacitor 403e is formed including a pixel electrode 481 connected to the wiring of the TFT 401d, the wiring 458, and a second gate insulating layer 379.

The TFT 401a illustrated in FIG. 12 is different from the TFT 401a illustrated in FIG. 10 in that the gate electrode 303 and the wiring 452 connecting the TFT 401a and the TFT 401b are connected through a wiring 483, which is formed at the same time as the pixel electrode 481 is formed over the second gate insulating layer 379 as illustrated in FIG. 13A.

The TFT 403c includes, over the substrate 301, the gate electrode 305, the first semiconductor layer 428a to which an impurity element imparting one conductivity type is added, the second semiconductor layer 428b, the third semiconductor layer 471, the first gate insulating layer 309 provided between the gate electrode 305 and the first semiconductor layer 428a, the impurity semiconductor layers 463 and 464 which are in contact with the third semiconductor layer 471 and function as a source region and a drain region, and the wirings 454 and 455 which are in contact with the impurity semiconductor layers 463 and 464. The TFT 403c also includes the back gate electrode 482 to face the gate electrode 305 with the second gate insulating layer 379 interposed therebetween. The back gate electrode 482 can be formed at the same time as the pixel electrode 481.

Further, the dual-gate TFT 300c shown in the aforementioned (structure 1) may be formed instead of the TFT 403c.

The pixel electrode 481 connected to the TFT 401d is formed over the second gate insulating layer 379.

The capacitor 403e is formed by including the wiring 458, the second gate insulating layer 379, and the pixel electrode 481.

In the display device illustrated in FIG. 12, the back gate electrode 482, and the wiring 483 connecting the gate electrode 303 and the wiring 452 can be formed at the same time as the pixel electrode 481 is formed; therefore, the number of photomasks can be reduced.

22

Next, FIGS. 14A and 14B illustrate a cross-sectional view of one mode (structure 4) of an EDMOS circuit applicable to the aforementioned (structure 1) to (structure 3).

FIG. 14A illustrates an EDMOS circuit of the logic circuit portion 391 in the display device. As a depletion type TFT 480a of the EDMOS circuit, as shown in the aforementioned (structure 2) and (structure 3), a TFT including the first semiconductor layer in which an impurity element imparting one conductivity type is added to the channel formation region is formed. An enhancement type TFT 480b is also formed with the same structure as the TFT 300b shown in (structure 1). Note that C-D in a cross-sectional view of the logic circuit portion 391 illustrated in FIG. 14A corresponds to C-D in a top view of FIG. 14B.

In the EDMOS circuit illustrated in FIGS. 14A and 14B, a gate electrode 486 of the depletion type TFT 480a is directly connected to a wiring 485 connecting the depletion type TFT 480a and the enhancement type TFT 480b in an opening portion formed in the first gate insulating layer 309.

Because the gate electrode 486 and the wiring 485 are connected directly, a contact resistance of the gate electrode 486 and the wiring 485 can be lower than in the EDMOS circuits illustrated in FIG. 7, FIGS. 8A and 8B, FIGS. 9A and 9B, FIG. 10, FIGS. 11A and 11B, and FIG. 12.

Note that in the case where a field effect mobility of a TFT is less than $5 \text{ cm}^2/\text{V}\cdot\text{sec}$, typically $0.5 \text{ cm}^2/\text{V}\cdot\text{sec}$ to $3 \text{ cm}^2/\text{V}\cdot\text{sec}$, as shown in (structure 1) to (structure 3), by connecting a depletion type TFT and an enhancement type TFT and forming a wiring connected to a gate electrode of the depletion type TFT at the same time as a back gate electrode or a pixel electrode is formed, the number of masks can be reduced. On the other hand, in the case where a field effect mobility of a TFT is greater than or equal to $5 \text{ cm}^2/\text{V}\cdot\text{sec}$, as illustrated in FIGS. 14A and 14B, the wiring connecting the depletion type TFT and the enhancement type TFT is directly connected to the gate electrode of the depletion type TFT in the opening portion formed in the first gate insulating layer 309, so that increase in a contact resistance can be reduced and high-speed operation of the TFT can be maintained.

Note that the TFTs in the EDMOS circuits in (structure 1) to (structure 4) can be appropriately applied to an inverter, a shift register, a buffer circuit, a protection circuit, a diode, and the like.

As to the TFTs shown in (structure 1) to (structure 4), a structure in which only the first semiconductor layer and the third semiconductor layer are stacked between the first gate insulating layer and the impurity semiconductor layer may be employed.

As to the aforementioned display device, the TFTs formed in the driver circuit and the pixel portion are TFTs with inverted staggered structure, and each TFT can be formed with one polarity, such as an n-type TFT or a p-type TFT, and further, part of the driver circuit can be formed over the substrate; therefore, the cost of the display device can be reduced. Further, by providing a dual-gate TFT or a depletion type TFT for a TFT that needs a large amount of current, the area of the TFT can be reduced, the frame of the display device can be narrowed, and a display region can be enlarged. In the pixel portion, a TFT of which on current is high and off current is low is used for the switching element of each pixel, so that a display device with high contrast and high image quality can be achieved.

Embodiment 4

Now, a manufacturing method of the display device in FIG. 7 will be described with reference to FIGS. 15A to 15C,

23

FIGS. 16A to 16C, FIGS. 17A and 17B, and FIGS. 18A and 18B. In this Embodiment, a manufacturing method of an n-type thin film transistor (method 1) will be described.

As illustrated in FIG. 15A, the gate electrodes 303 to 306 and the capacitor wiring 307 are formed over the substrate 301. Next, the first gate insulating layer 309 and a first semiconductor layer 311 are formed in this order covering the gate electrodes 303 to 306 and the capacitor wiring 307.

As the substrate 301, the substrate 301 described in Embodiment 3 can be used appropriately.

The gate electrodes 303 to 306 and the capacitor wiring 307 are formed using the material of the gate electrodes 303 to 306 and the capacitor wiring 307 described in Embodiment 3 appropriately. The gate electrodes 303 to 306 and the capacitor wiring 307 can be formed as follows: a conductive layer is formed over the substrate 301 using the aforementioned material by a sputtering method or a vacuum evaporation method, then a mask is formed over the conductive layer by photolithography, an inkjet method, or the like, and the conductive layer is etched using the mask. Alternatively, the gate electrodes 303 to 306 and the capacitor wiring 307 can be formed by discharging a conductive nanopaste of silver, gold, copper, or the like to the substrate by an inkjet method and baking the conductive nanopaste. In order to improve adhesion between the gate electrodes 303 to 306 and the capacitor wiring 307 and the substrate 301, a layer of a nitride of the aforementioned metal material may be provided between the substrate 301 and the gate electrodes 303 to 306 and the capacitor wiring 307. Hereupon, a conductive layer is formed over the substrate 301 and etched with a resist mask formed using a photomask.

Note that side surfaces of the gate electrodes 303 to 306 and the capacitor wiring 307 are preferably a tapered shape. This is because an insulating layer, a semiconductor layer, and a wiring layer, which are formed over the gate electrode 303 in subsequent steps are not disconnected. In order to form the side surfaces of the gate electrodes 303 to 306 and the capacitor wiring 307 into a tapered shape, etching is performed while a resist mask is being reduced.

Further, the gate wiring (the scan line) and the capacitor wiring can be formed at the same time as the step for forming the gate electrodes 303 to 306. Note that a "scan line" means a wiring arranged to select a pixel, while a "capacitor wiring" means a wiring connected to one electrode of a storage capacitor of a pixel. However, the present invention is not limited to this and one or both of the gate wiring and the capacitor wiring may be provided in a different step from the gate electrodes 303 to 306.

The first gate insulating layer 309 can be formed with the same material as the first gate insulating layer 309 described in Embodiment 3 appropriately. The first gate insulating layer 309 can be formed by a CVD method, a sputtering method, or the like. Alternatively, the first gate insulating layer 309 may be formed with a microwave plasma CVD apparatus with a high frequency of the greater than or equal to 1 GHz or the like. In the case where the first gate insulating layer 309 is formed with the microwave plasma CVD apparatus, a thin film transistor with high reliability can be obtained because a withstand voltage between the gate electrodes and the source and drain electrodes can be improved. Alternatively, in the case where a silicon oxide layer is formed as the first gate insulating layer 309 by a CVD method using an organosilane gas, a hydrogen content of the first gate insulating layer can be reduced and fluctuation of the threshold voltage of the thin film transistor can be reduced. As the organosilane gas, a silicon-containing compound such as tetraethoxysilane (TEOS: chemical formula, $\text{Si}(\text{OC}_2\text{H}_5)_4$), tetramethylsilane

24

(TMS: chemical formula, $\text{Si}(\text{CH}_3)_4$), tetramethylcyclotetrasiloxane (TMCTS), octamethylcyclotetrasiloxane (OMCTS), hexamethyldisilazane (HMDS), triethoxysilane ($\text{SiH}(\text{OC}_2\text{H}_5)_3$), or trisdimethylaminosilane ($\text{SiH}(\text{N}(\text{CH}_3)_2)_3$) can be used.

The first semiconductor layer 311 is formed using microcrystalline silicon, microcrystalline silicon germanium, microcrystalline germanium, or the like. The first semiconductor layer 311 is formed with a thickness of greater than or equal to 1 nm and less than or equal to 20 nm, preferably, greater than or equal to 3 nm and less than or equal to 10 nm.

The first semiconductor layer 311 is formed by glow discharge plasma with a mixture of a deposition gas including silicon or germanium and hydrogen in a reaction chamber of the plasma CVD apparatus. Alternatively, the first semiconductor layer 311 is formed by glow discharge plasma with a mixture of a deposition gas including silicon or germanium, hydrogen, and a rare gas such as helium, neon, or krypton. When microcrystalline silicon, microcrystalline silicon germanium, microcrystalline germanium or the like is formed, the deposition gas containing silicon or germanium is diluted with hydrogen so that the flow rate of hydrogen is 10 to 2000 times, preferably 10 to 200 times that of the deposition gas containing silicon or germanium.

As typical examples of the deposition gas including silicon or germanium, SiH_4 , Si_2H_6 , GeH_4 , Ge_2H_6 are given.

Note that, before the first semiconductor layer 311 is formed, while a gas in the treatment chamber of the CVD apparatus is exhausted, the deposition gas including silicon or germanium is introduced to a treatment chamber and impurity elements in the treatment chamber are removed. In that case, impurity elements, at the interface between the first gate insulating layer 309 and the first semiconductor layer of the thin film transistor which is formed in a later step can be reduced and electric characteristics of the thin film transistor can be improved.

Next, as illustrated in FIG. 15B, a second semiconductor layer 313 and a third semiconductor layer 315 are formed over the first semiconductor layer 311. Here, the second semiconductor layer 313 and the third semiconductor layer 315 are formed under the condition that crystals grow partially from the first semiconductor layer 311. The second semiconductor layer 313 and the third semiconductor layer 315 are formed by glow discharge plasma with a mixture of a deposition gas including silicon or germanium and hydrogen in a reaction chamber of the plasma CVD apparatus. At this time, instead of the condition of forming the first semiconductor layer 311, the layers are formed under the condition that the flow ratio of hydrogen to the deposition gas including silicon or germanium is reduced, which is a condition that crystal growth is reduced; thus, crystal growth of the second semiconductor layer 313 is suppressed, and as a film is deposited, the third semiconductor layer 315 which does not include microcrystalline semiconductor regions can be formed.

Alternatively, in a reaction chamber of the plasma CVD apparatus, the second semiconductor layer 313 and the third semiconductor layer 315 are formed by glow discharge plasma with a mixture of a deposition gas including silicon or germanium, hydrogen, and a gas including nitrogen. At this time, instead of the condition of forming the first semiconductor layer 311, the layers are formed under the condition that the flow ratio of hydrogen to the deposition gas including silicon or germanium is reduced and the gas including nitrogen is mixed; thus, crystal growth of the second semiconductor layer 313 is suppressed, and the third semiconductor layer 315 which does not include microcrystalline semiconductor regions can be formed.

25

In this Embodiment, in an early stage of deposition of the second semiconductor layer **313**, the first semiconductor layer **311** serves as a seed crystal and a film is deposited over the entire surface. After that, crystal growth is partially suppressed and conical or pyramidal shape microcrystalline semiconductor regions are formed (a middle stage of deposition). Further, crystal growth of the conical or pyramidal shape microcrystalline semiconductor regions is suppressed and the third semiconductor layer **315** that does not include microcrystalline semiconductor regions is formed (a later stage of deposition). Accordingly, the first semiconductor layer described in Embodiment 3 corresponds to a film that is formed at an initial stage of deposition of the first semiconductor layer **311** and the second semiconductor layer **313** in this Embodiment. The second semiconductor layer described in Embodiment 3 corresponds to the conical or pyramidal shape microcrystalline semiconductor regions and the amorphous semiconductor regions, which are formed in the middle stage of deposition of the second semiconductor layer **313** in this Embodiment. The third semiconductor layer described in Embodiment 3 corresponds to the third semiconductor layer **315** that is formed in the later stage of deposition in this Embodiment.

Next, as illustrated in FIG. **15C**, a semiconductor layer to which an impurity element imparting one conductivity type is added (hereinafter, referred to as an impurity semiconductor layer **317**) is formed over the third semiconductor layer **315**, and a conductive layer **319** is formed over the impurity semiconductor layer **317**.

The impurity semiconductor layer **317** is formed by glow discharge plasma with a mixture of a deposition gas including silicon or germanium, hydrogen, and phosphine (diluted with hydrogen or silane) in a reaction chamber of the plasma CVD apparatus. By diluting the deposition gas including silicon or germanium with hydrogen, amorphous silicon to which phosphorus is added, microcrystalline silicon to which phosphorus is added, amorphous silicon germanium to which phosphorus is added, microcrystalline silicon germanium to which phosphorus is added, amorphous germanium to which phosphorus is added, microcrystalline germanium to which phosphorus is added, or the like is formed.

The materials and the stacked-layer structure of the wirings **346** to **352** and the capacitor wiring **353** in Embodiment 3 can be appropriately employed for the conductive layer **319**. The conductive layer **319** is formed by a CVD method, a sputtering method, or a vacuum evaporation method. Alternatively, the conductive layer **319** may be formed as follows: a conductive nanopaste of silver, gold, copper, or the like is discharged by using a screen printing method, an inkjet method, or the like, and baked.

Next, as illustrated in FIG. **16A**, second resist masks **321** to **324** are formed over the conductive layer **319**.

The resist masks **321** to **323** each include regions having different thicknesses. Such resist masks can be formed by use of a multi-tone mask. The use of the multi-tone mask is preferable because the numbers of photomasks is reduced and the number of manufacturing steps is reduced. In this Embodiment, a multi-tone mask can be used in a step of forming a pattern of the semiconductor layer and a step of separating the semiconductor layer into a source region and a drain region.

A multi-tone mask is a mask capable of light exposure with multi-level light intensity, and typically, light exposure is performed with three levels of light intensity to provide an exposed region, a half-exposed region, and an unexposed region. By use of the multi-tone mask, one-time light exposure and development process allow a resist mask with plural

26

thicknesses (typically, two levels of thicknesses) to be formed; therefore, by the use of a multi-tone mask, the number of photomasks can be reduced.

FIGS. **19A-1** and **19B-1** are cross-sectional views of typical multi-tone masks. FIG. **19A-1** illustrates a gray-tone mask **490** and FIG. **19B-1** illustrates a half-tone mask **495**.

The gray-tone mask **490** illustrated in FIG. **19A-1** includes a light-blocking portion **492** formed using a light-blocking film on a substrate **491** having a light-transmitting property, and a diffraction grating portion **493** provided with a pattern of the light-blocking film.

The transmittance of light is controlled at the diffraction grating portion **493** in such a manner that slits, dots, mesh, or the like are provided at an interval less than or equal to the resolution limit of light used for light exposure. Note that the slits, dots, or mesh provided at the diffraction grating portion **493** may be provided periodically or non-periodically.

As the substrate **491** having a light-transmitting property, quartz or the like can be used. The light-blocking film for forming the light-blocking portion **492** and the diffraction grating portion **493** may be formed using metal, preferably, chromium, chromium oxide, or the like.

In the case where the gray-tone mask **490** is irradiated with light for light exposure, as illustrated in FIG. **19A-2**, the transmittance of part of the gray-tone mask **490** which overlaps with the light-blocking portion **492** is 0%, and the transmittance of part of the gray-tone mask **490** where both the light-blocking portion **492** and the diffraction grating portion **493** are not provided is 100%. Further, the transmittance at the diffraction grating portion **493** is substantially in the range of 10% to 70%, which can be adjusted by the interval of slits, dots, or mesh of the diffraction grating, or the like.

The half-tone mask **495** illustrated in FIG. **19B-1** includes a semi-light-transmitting portion **497** formed using a semi-light-transmitting film on a substrate **496** having a light-transmitting property, and a light-blocking portion **498** formed using a light-blocking film.

The semi-light-transmitting portion **497** can be formed using a film of MoSiN, MoSi, MoSiO, MoSiON, CrSi, or the like. The light-blocking portion **498** may be formed using metal that is a material similar to the light-blocking film of the gray-tone mask and preferably provided using chromium, chromium oxide, or the like.

In the case where the half-tone mask **495** is irradiated with light for light exposure, as illustrated in FIG. **19B-2**, the transmittance of part of the half-tone mask **495** which overlaps with the light-blocking portion **498** is 0%, and the transmittance of part of the half-tone mask **495** where both the light-blocking portion **498** and the semi-light-transmitting portion **497** are not provided is 100%. Further, the transmittance in the semi-light-transmitting portion **497** is substantially in the range of 10% to 70%, which can be adjusted by the kind, the thickness, or the like of the semi-light-transmitting portion **497** to be formed.

By light exposure and development using the multi-tone mask, a resist mask that includes regions having different thicknesses can be formed.

Next, the first semiconductor layer **311**, the second semiconductor layer **313**, the third semiconductor layer **315**, the impurity semiconductor layer **317**, and the conductive layer **319** are etched using the resist masks **321** to **324**. By this step, the first semiconductor layer **311**, the second semiconductor layer **313**, the third semiconductor layer **315**, the impurity semiconductor layer **317**, and the conductive layer **319** are divided to be used for each element, so that the first semiconductor layers **333a** to **336a**, the second semiconductor layers **333b** to **336b**, the third semiconductor layers **333c** to **336c**,

27

the impurity semiconductor layers 329 to 332, and the conductive layers 325 to 328 are formed (see FIG. 16B).

Next, the resist masks 321 to 324 are reduced in size, so that the resist masks 337 to 344, which are separated and the resist mask 345 that is reduced are formed. In order to reduce the resist masks, ashing with oxygen plasma may be used. Here, the resist masks 321 to 323 are subjected to ashing in order to be separated over the gate electrodes; thus, resist masks 337 to 344 can be formed (see FIG. 16C).

Next, the conductive layers 325 to 328 are etched using the resist masks 337 to 345 in order to form wirings 346 to 352 and the capacitor wiring 353 (see FIG. 17A). It is preferable to employ wet etching as the etching of the conductive layers 325 to 328. By wet etching, the conductive layers 325 to 328 are isotropically etched. As a result, the side surface of the wirings 346 to 352 and the capacitor wiring 353 are reduced to an inner side than the side surface of the resist masks 337 to 345. The wirings 346 to 352 serve as not only a source electrode and a drain electrode but also as a signal line. However, without limitation thereto, a signal line may be provided separately from source and drain electrodes.

Next, part of each of the third semiconductor layers 333c to 336c and the impurity semiconductor layers 329 to 332 is etched using the resist masks 337 to 345. Here, dry etching is employed. The third semiconductor layers 363 to 366, which each serves as a buffer layer, and the impurity semiconductor layers 355 to 362 are formed up to this step. After this step, the resist masks 337 to 345 are removed (see FIG. 17A). Note that a cross-sectional view illustrating a pixel portion 395 in FIG. 17A corresponds to a cross-sectional view along a line A-B of the pixel portion in a plane view of FIG. 20A.

In this case, after the conductive layers 325 to 328 are etched by wet etching, part of each of the third semiconductor layers 333c to 336c and the impurity semiconductor layers 329 to 332 is etched by dry etching while the resist masks 337 to 345 remain. Thus, the conductive layers 325 to 328 are isotropically etched, and the side surfaces of the wirings 346 to 352 and the capacitor wiring 353 do not match the side surfaces of the impurity semiconductor layers 355 to 362, that is, the side surfaces of the impurity semiconductor layers 355 to 362 are formed outside of the wirings 346 to 352 and the capacitor wiring 353.

After the resist masks 337 to 345 are removed, it is preferable that dry etching be performed on the third semiconductor layers 363 to 366. The dry etching condition is set such that an exposed part of each of the third semiconductor layers 363 to 366 is not damaged and the etching rate to the third semiconductor layers 363 to 366 is low. That is, condition that an exposed surface of each of the third semiconductor layers 363 to 366 is hardly damaged and the thickness thereof is hardly reduced is employed. As an etching gas, Cl₂, CF₄, N₂, or the like is used. An etching method is not particularly limited and an inductively coupled plasma (ICP) method, a capacitively coupled plasma (CCP) method, an electron cyclotron resonance (ECR) method, or a reactive ion etching (RIE) method, or the like can be used.

Next, the surfaces of the third semiconductor layers 363 to 366 may be irradiated with water plasma, ammonia plasma, nitrogen plasma, or the like.

The water plasma treatment can be performed in such a manner that a gas containing water as its main component typified by water vapor (H₂O vapor) is introduced into a reaction space and generate plasma.

As described above, dry etching is further performed under the condition that the third semiconductor layers 363 to 366 are not damaged after the impurity semiconductor layers 355 to 362 are formed, so that impurities such as residues or the

28

like on the third semiconductor layers 363 to 366 can be removed. Further, by performing the water plasma treatment after the dry etching, residues on the resist masks can be removed. By the water plasma treatment, insulation between the source region and the drain region can be secured, and thus in a thin film transistor which is completed, the off current can be reduced, and variation in the electric characteristics can be reduced.

Through the above-described steps, the thin film transistor can be manufactured.

Next, a second gate insulating layer 371 is formed. After that, over the first gate insulating layer 309, back gate electrodes 373 and 374, and a capacitor wiring 375 are formed in a region where the dual-gate TFT 300a of the logic circuit portion 391 is formed, a region where the dual-gate TFT 300c of the switch portion 393 is formed, and a region where the capacitor of the pixel portion 395 is formed, respectively.

The second gate insulating layer 371 can be formed in a manner similar to the first gate insulating layer 309.

The materials and the manufacturing method of the wirings 346 to 352 and the capacitor wiring 353 can be appropriately used for forming the back gate electrodes 373 and 374, and the capacitor wiring 375.

Next, as illustrated in FIG. 18A, an insulating layer 372 is formed. The insulating layer 381 described in Embodiment 3 can be appropriately used for forming the insulating layer 372.

Next, the insulating layer 372 and of the second gate insulating layer 371 are partly etched to form an opening through which the wiring 347 connecting the dual-gate TFT 300a and the TFT 300b of the logic circuit portion 391, the gate electrode 303, and the wiring 352 of the pixel portion 395 are exposed. The opening can be formed by photolithography. After that, a wiring 347 and a pixel electrode 383 are formed over the insulating layer 372. Through the opening, the wiring 347 connects the wiring 347 connecting the dual-gate TFT 300a and the TFT 300b to the gate electrode 303, and the pixel electrode 383 connects to the wiring 352 of the pixel portion 395 (see FIG. 18B, and see FIG. 8A about the connection of the wiring 347 and the gate electrode 303.). Note that a cross-sectional view of the pixel portion 395 illustrated in FIG. 18A corresponds to a cross-sectional view along A-B of the pixel portion in a plane view of FIG. 20B.

A thin film is formed using the materials described in Embodiment 3 by a sputtering method, and the film is etched using a resist mask that is formed by a photolithography process, so that the wiring 384 and the pixel electrode 383 can be formed. Alternatively, a conductive composition including a conductive high molecule having a light-transmitting property is applied or printed, and baked to form the wiring 384 and the pixel electrode 383. Note that a cross-sectional view of the pixel portion 395 illustrated in FIG. 17A corresponds to a cross sectional view along A-B of the pixel portion in a plane view of FIG. 20A.

By connecting the wiring 347 connecting the dual-gate TFT 300a and the TFT 300b of the logic circuit portion 391 to the gate electrode 303 through the wiring 384, an EDMOS circuit including the TFT 300a and the TFT 300b can be formed.

Through the above-described steps, the display device illustrated in FIGS. 8A and 8B can be manufactured.

Next, a manufacturing method of the display device in FIG. 10 (method 2) will be described with reference to FIGS. 21A to 21C, FIGS. 22A to 22C, and FIGS. 23A and 23B.

As illustrated in FIG. 21A, the gate electrodes 303 to 306 and the capacitor wiring 307 are formed over the substrate 301. Next, the first gate insulating layer 309 and the first

29

semiconductor layer **411** to which an impurity element imparting one conductivity type is added are formed covering the gate electrodes **303** to **306** and the capacitor wiring **307**.

As the substrate **301**, the substrate **301** described in Embodiment 3 can be used appropriately.

The gate electrodes **303** to **306** and the capacitor wiring **307** and the first gate insulating layer **309** can be formed in a manner similar to the aforementioned (method **1**).

The first semiconductor layer **411** to which an impurity element imparting one conductivity type is added is formed by adding an impurity element serving as a donor or an acceptor to the first semiconductor layer **311**. As the impurity element serving as a donor, an element belonging to Group 15 of the periodic table, typically, phosphorus, arsenic, antimony, or the like is used. As the impurity element serving as an acceptor, an element belonging to Group 13 of the periodic table, typically, boron, or the like is used. Hereupon, as a method for forming the first semiconductor layer **411** to which an impurity element imparting one conductivity type is added, a microcrystalline semiconductor layer to which phosphorus, which is an impurity element serving as a donor, is added is described.

A semiconductor layer is formed by mixing a gas containing an impurity element imparting one conductivity type to a source gas of the first semiconductor layer **411** to which an impurity element imparting one conductivity type is added. Typically, the semiconductor layer is formed by glow discharge plasma with a mixture of a deposition gas containing silicon or germanium, hydrogen, and phosphine in a reaction chamber of the plasma CVD apparatus. Alternatively, the semiconductor layer is formed by glow discharge plasma with a mixture of a deposition gas including silicon or germanium, hydrogen, phosphine, and a rare gas such as helium, neon, or krypton. As the first semiconductor layer **411** to which an impurity element imparting one conductivity type is added, microcrystalline silicon including phosphorus, microcrystalline silicon germanium including phosphorus, microcrystalline germanium including phosphorus, or the like is formed.

Alternatively, a microcrystalline semiconductor layer is formed after the surface of the first gate insulating layer **309** is exposed to a gas containing an impurity element imparting one conductivity type; thus, the microcrystalline semiconductor layer is formed while taking in an impurity element imparting one conductivity type. Typically, the surface of the first gate insulating layer **309** is exposed to phosphine; thus, phosphorus is adsorbed to the surface of the first gate insulating layer **309**. After that, the microcrystalline semiconductor layer is formed in a manner similar to the first semiconductor layer **311** described in the (method **1**), so that microcrystalline silicon including phosphorus, microcrystalline silicon germanium including phosphorus, microcrystalline germanium including phosphorus, or the like can be formed.

Alternatively, after a microcrystalline semiconductor layer is formed over the first gate insulating layer **309**, plasma is generated under a gas atmosphere containing an impurity element imparting one conductivity type, and the microcrystalline semiconductor layer is exposed to plasma containing an impurity element imparting one conductivity type; thus, the first semiconductor layer **411** to which an impurity element imparting one conductivity type is added can be formed. Typically, after the microcrystalline semiconductor layer is formed in a manner similar to the first semiconductor layer **311** described in (method **1**), the microcrystalline semiconductor layer is exposed to phosphorus plasma, so that microcrystalline silicon including phosphorus, microcrystalline

30

silicon germanium including phosphorus, microcrystalline germanium including phosphorus, or the like can be formed.

Next, after the second semiconductor layer **413**, the third semiconductor layer **415**, and the impurity semiconductor layer **417** are formed over the first semiconductor layer **411**, resist masks **419** and **420** are formed over the impurity semiconductor layer **417** (see FIG. **21B**).

Here, the second semiconductor layer **413**, the third semiconductor layer **415**, and the impurity semiconductor layer **417** are formed in a manner similar to the aforementioned the second semiconductor layer **313**, the third semiconductor layer **315**, and the impurity semiconductor layer **317** described in (method **1**).

Note that the thickness of the impurity semiconductor layer **417** is reduced by the subsequent steps of etching a fourth semiconductor layer **431**, a fifth semiconductor layer **433**, a sixth semiconductor layer **435**, and an impurity semiconductor layer **437**. Accordingly, it is preferable that the impurity semiconductor layer **417** be formed thickly, typically, with a thickness of about 30 nm to 150 nm.

The resist masks **419** and **420** are formed in a region to be a TFT **401a** of the logic circuit portion **391** later and a region to be a TFT **401c** of the switch portion **393** later respectively.

Next, the first semiconductor layer **411**, the second semiconductor layer **413**, the third semiconductor layer **415**, and the impurity semiconductor layer **417** are etched using the resist masks **419** and **420**. By this step, the first semiconductor layer **411**, the second semiconductor layer **413**, the third semiconductor layer **415**, and the impurity semiconductor layer **417** are divided to be used for each element, so that the first semiconductor layers **427a** and **428a**, the second semiconductor layers **427b** and **428b**, the third semiconductor layers **425** and **426**, and the impurity semiconductor layers **423** and **424** are formed. After that, the resist masks **419** and **420** are removed (see FIG. **21C**).

As illustrated in FIG. **22A**, the fourth semiconductor layer **431**, the fifth semiconductor layer **433**, the sixth semiconductor layer **435**, and the impurity semiconductor layer **437** are formed, and resist masks **439** and **440** are formed thereover.

The fourth semiconductor layer **431**, the fifth semiconductor layer **433**, the sixth semiconductor layer **435**, and the impurity semiconductor layer **437** can be formed in a manner similar to the first semiconductor layer **311**, the second semiconductor layer **313**, the third semiconductor layer **315**, and the impurity semiconductor layer **317** described in the aforementioned (method **1**) respectively.

The resist masks **439** and **440** are formed in a region to be a TFT **401b** of the logic circuit portion **391** later and in a region to be a TFT **401d** of the pixel portion **395** later respectively.

Next, the fourth semiconductor layer **431**, the fifth semiconductor layer **433**, the sixth semiconductor layer **435**, and the impurity semiconductor layer **437** are etched using the resist masks **439** and **440**. By this step, the fourth semiconductor layer **431**, the fifth semiconductor layer **433**, the sixth semiconductor layer **435**, and the impurity semiconductor layer **437** are divided to be used for each element, so that the fourth semiconductor layers **454a** to **456a**, the fifth semiconductor layers **454b** to **456b**, the sixth semiconductor layers **454c** to **456c**, and the impurity semiconductor layers **444**, **446**, and **447** are formed. By the etching, the impurity semiconductor layers **423** and **424** are also etched, so that impurity semiconductor layers **443** and **445** whose thicknesses are reduced are formed. This is because the fourth semiconductor layer **431**, the fifth semiconductor layer **433**, the sixth semiconductor layer **435**, and the impurity semiconductor layer **437** are sufficiently etched and over etching is performed after

31

the etching of the fourth semiconductor layer **431** is completed so as not to leave residues. Accordingly, the impurity semiconductor layers **423** and **424** are also etched by the over etching (see FIG. 22B). After that, the resist masks **439** and **440** are removed.

Next, illustrated in FIG. 22C, the conductive layer **319** is formed.

Next, a resist mask is formed over the conductive layer **319**. Next, the conductive layer **319** is etched using the resist mask in a manner similar to the aforementioned (method 1) to form wirings **451** to **458**.

Next, part of each of the third semiconductor layers **469** to **473** and part of each of the impurity semiconductor layers **443** to **447** are etched in a manner similar to the aforementioned (method 1) using the resist mask. The third semiconductor layers **469** to **473**, which each serves as a buffer layer, and the impurity semiconductor layers **459** to **467** are formed up to this step. After that, the resist mask is removed.

After removing the resist mask, dry etching is preferably performed. The surfaces of the third semiconductor layers **469** to **473** may be irradiated with water plasma, ammonia plasma, nitrogen plasma, or the like.

Next, the second gate insulating layer **371** and the insulating layer **372** are formed in a manner similar to the aforementioned (method 1) (see FIG. 23A).

Through the above-described steps, the thin film transistor can be manufactured.

Next, part of each of the second gate insulating layer **371** and the insulating layer **372** is etched to form an opening through which the wiring **452** of a TFT **401a** of the logic circuit portion **391**, the gate electrode **303**, and the wiring **457** of the pixel portion **395** are exposed. The opening can be formed by photolithography. After that, a wiring **384** and a pixel electrode **383** are formed over the insulating layer **372**. Through the opening, the wiring **384** connects the wiring **452** of the TFT **401a** of the logic circuit portion **391** and the gate electrode **303**, and the pixel electrode **383** is connected to the wiring **457** of the pixel portion **395** (see FIG. 23B, and see FIG. 11A about the connection of the wiring **384** and the gate electrode **303**).

By connecting the wiring **452** of the TFT **401a** of the logic circuit portion **391** and the gate electrode **303** through the wiring **384**, an EDMOS circuit including the TFT **401a** and the TFT **401b** can be formed.

Embodiment 5

In this Embodiment, the protection circuits provided in a display device, which is an embodiment of the present invention, will be described with reference to the accompanying drawings. Examples of specific circuit structures of the protection circuits **134** to **136** of FIG. 2 in Embodiment 1 are described with reference to FIGS. 24A to 24F. Although only a case of providing an n-type transistor will be described, the present invention is not limited thereto.

A protection circuit illustrated in FIG. 24A includes protection diodes **501** to **504** each using a plurality of thin film transistors. The protection diode **501** includes an n-type thin film transistor **501a** and an n-type thin film transistor **501b**, which are connected in series. One of a source electrode and a drain electrode of the n-type thin film transistor **501a** is connected to a gate electrode of the n-type thin film transistor **501a** and a gate electrode of the n-type thin film transistor **501b** and is kept at a potential V_{ss} . The other of the source electrode and the drain electrode of the n-type thin film transistor **501a** is connected to one of a source electrode and a drain electrode of the n-type thin film transistor **501b**. The

32

other of the source electrode and the drain electrode of the n-type thin film transistor **501b** is connected to the protection diode **502**. Further, in a manner similar to the protection diode **501**, the protection diodes **502** to **504** each include a plurality of thin film transistors connected in series, and an end of the plurality of thin film transistors connected in series is connected to gate electrodes of the plurality of thin film transistors.

Note that in the present invention, the number and polarity of the thin film transistors included in each of the protection diodes **501** to **504** are not limited to those illustrated in FIG. 24A. For example, the protection diode **501** may be formed including three thin film transistors connected in series.

The protection diodes **501** to **504** are sequentially connected in series, and a node between the protection diode **502** and the protection diode **503** is connected to a wiring **505**. Note that the wiring **505** is a wiring electrically connected to a semiconductor element which is to be protected. Note that a wiring connected to the wiring **505** is not limited to the wiring between the protection diode **502** and the protection diode **503**. That is, the wiring **505** may be connected between the protection diode **501** and the protection diode **502**, or may be connected between the protection diode **503** and the protection diode **504**.

One end of the protection diode **504** is kept at a power supply potential V_{dd} . In addition, each of the protection diodes **501** to **504** is connected so that a reverse bias voltage is applied thereto.

Note that the structure of the protection circuit illustrated in FIG. 24A can be changed as illustrated in FIG. 24B: the protection diodes **501** and **502** are replaced with a protection diode **506** and the protection diodes **503** and **504** are replaced with a protection diode **507**.

A protection circuit illustrated in FIG. 24C includes a protection diode **510**, a protection diode **511**, a capacitor **512**, a capacitor **513**, and a resistor **514**. The resistor **514** is a resistor having two terminals. A potential V_{in} is supplied to one of the terminals of the resistor **514** from a wiring **515**. The potential V_{ss} is supplied to the other of the terminals of the resistor **514**. The resistor **514** is provided in order to make the potential of the wiring **515** V_{ss} when the potential V_{in} is not supplied, and the resistance value of the resistor **514** is set so as to be sufficiently larger than the wiring resistance of the wiring **515**. A diode-connected n-type thin film transistor is used for each of the protection diode **510** and the protection diode **511**.

Note that for the protection diodes illustrated in FIG. 24C, two or more thin film transistors may be connected in series.

In a protection circuit illustrated in FIG. 24D, two n-type thin film transistors are used for each of the protection diode **510** and the protection diode **511**.

Note that although diode-connected n-type thin film transistors are used for the protection diodes in the protection circuits illustrated in FIGS. 24C and 24D, this embodiment is not limited to this structure.

The protection circuit illustrated in FIG. 24E includes protection diodes **520** to **527** and a resistor **528**. The resistor **528** is connected between a wiring **529A** and a wiring **529B** in series. A diode-connected n-type thin film transistor is used for each of the protection diodes **520** to **527**.

The protection diode **520** and the protection diode **521** are connected in series, one end thereof is kept at the potential V_{ss} , and the other end thereof is connected to the wiring **529A** of the potential V_{in} . The protection diode **522** and the protection diode **523** are connected in series, one end thereof is kept at the potential V_{dd} , and the other end thereof is connected to the wiring **529A** of the potential V_{in} . The protection diode **524**

and the protection diode **525** are connected in series, one end thereof is kept at the potential V_{ss} , and the other end thereof is connected to the wiring **529B** of the potential V_{out} . The protection diode **526** and the protection diode **527** are connected in series, one end thereof is kept at the potential V_{dd} , and the other end thereof is connected to the wiring **529B** of the potential V_{out} .

A protection circuit illustrated in FIG. **24F** includes a resistor **530**, a resistor **531**, and a protection diode **532**. Although a diode-connected n-type thin film transistor is used for the protection diode **532** in FIG. **24F**, this embodiment is not limited to this structure. A plurality of diode-connected thin film transistors may be used. The resistor **530**, the resistor **531**, and the protection diode **532** are connected to a wiring **533** in series.

The resistor **530** and the resistor **531** can relieve a steep change in the potential of the wiring **533** and can prevent deterioration and damage of a semiconductor element. Further, the protection diode **532** can prevent a reverse bias current from flowing through the wiring **533** due to change in potential.

Note that when only the resistors are connected to the wiring in series, a steep change in the potential of the wiring can be relieved and deterioration and damage of a semiconductor element can be prevented. Further, only the protection diode is connected to the wiring in series, the protection diode can prevent a reverse bias current from flowing through the wiring due to change in potential.

Here, the case where the protection circuits illustrated in FIGS. **24A** to **24F** are operated is described. At this time, one of the electrodes of each of the protection diodes **501**, **502**, **506**, **511**, **520**, **521**, **524**, and **525**, which is kept at the potential V_{ss} , is a drain electrode, and the other electrode is a source electrode. One of the electrodes of each of the protection diodes **503**, **504**, **507**, **510**, **522**, **523**, **526**, and **527**, which is kept at the potential V_{dd} , is a source electrode, and the other electrode is a drain electrode. In addition, the threshold voltage of the thin film transistors included in the protection diodes is denoted by V_{th} .

Further, as for the protection diodes **501**, **502**, **506**, **511**, **520**, **521**, **524**, and **525**, when the potential V_{in} is higher than the potential V_{ss} , a reverse bias voltage is applied thereto and current does not easily flow therethrough. Meanwhile, as for the protection diodes **503**, **504**, **507**, **510**, **522**, **523**, **526**, and **527**, when the potential V_{in} is lower than the potential V_{dd} , a reverse bias voltage is applied thereto and current does not easily flow therethrough.

Here, operations of protection circuits in which a potential V_{out} is set almost between the potential V_{ss} and the potential V_{dd} are described.

First, the case where the potential V_{in} is higher than the potential V_{dd} is described. When the potential V_{in} is higher than the potential V_{dd} , the n-type thin film transistors are turned on when a potential difference between the gate electrodes and the source electrodes of the respective protection diodes **503**, **504**, **507**, **510**, **522**, **523**, **526**, and **527** satisfies $V_{gs} = V_{in} - V_{dd} > V_{th}$. Here, since the case where V_{in} is unusually high is assumed, the n-type thin film transistors are turned on. At this time, the n-type thin film transistors included in the protection diodes **501**, **502**, **506**, **511**, **520**, **521**, **524**, and **525** are turned off. Then, the potentials of the wirings **505**, **508**, **515**, **529A**, and **529B** become V_{dd} through the protection diodes **503**, **504**, **507**, **510**, **522**, **523**, **526**, and **527**. Therefore, even when the potential V_{in} is unusually higher than the potential V_{dd} due to noise or the like, the potentials of the wirings **505**, **508**, **515**, **529A**, and **529B** do not become higher than the potential V_{dd} .

On the other hand, in the case where the potential V_{in} is lower than the potential V_{ss} , the n-type thin film transistors are turned on when a potential difference between the gate electrodes and the source electrodes of the respective protection diodes **501**, **502**, **506**, **511**, **520**, **521**, **524**, and **525** satisfies $V_{gs} = V_{ss} - V_{in} > V_{th}$. Here, since the case where V_{in} is unusually low is assumed, the n-type thin film transistors are turned on. At this time, the n-type thin film transistors included in the protection diodes **503**, **504**, **507**, **510**, **522**, **523**, **526**, and **527** are turned off. Then, the potentials of the wirings **505**, **508**, **515**, **529A**, and **529B** become V_{ss} through the protection diodes **501**, **502**, **506**, **511**, **520**, **521**, **524**, and **525**. Therefore, even when the potential V_{in} is unusually lower than the potential V_{ss} due to noise or the like, the potentials of the wirings **505**, **508**, **515**, **529A**, and **529B** do not become lower than the potential V_{ss} . Further, the capacitor **512** and the capacitor **513** reduce pulsed noise of the input potential V_{in} and relieve a steep change in potential due to noise.

Note that when the potential V_{in} is between $V_{ss} - V_{th}$ and $V_{dd} + V_{th}$, all the n-type thin film transistors included in the protection diodes are turned off, and the potential V_{in} is outputted as the potential V_{out} .

When the protection circuits are provided as described above, the potentials of the wirings **505**, **508**, **515**, **529A**, and **529B** are kept almost between the potential V_{ss} and the potential V_{dd} . Therefore, the potentials of the wirings **505**, **508**, **515**, **529A**, and **529B** can be prevented from deviating from this range greatly. That is, the potentials of the wirings **505**, **508**, **515**, **529A**, and **529B** can be prevented from being unusually high or being unusually low, a circuit in the next stage of the protection circuits can be prevented from being damaged or deteriorating, and the circuit in the next stage can be protected.

Further, when the protection circuit including the resistor **514** is provided for an input terminal as illustrated in FIG. **24C**, the potentials of all the wirings to which a signal is inputted can be kept constant (here the potential V_{ss}) when a signal is not inputted. That is, when a signal is not inputted, the protection circuit also has a function of a short-circuit ring capable of short-circuiting the wirings. Therefore, electrostatic discharge caused by a potential difference between the wirings can be prevented. In addition, since the resistance value of the resistor **514** is sufficiently larger than wiring resistance, a signal inputted to the wiring can be prevented from dropping to the potential V_{ss} at the time of inputting the signal.

Here, as an example, the case is described in which n-type thin film transistors having a threshold voltage $V_{th} = 0$ are used for the protection diode **501** and the protection diode **511** in FIG. **24C**.

First, in the case of $V_{in} > V_{dd}$, the protection diode **510** is turned on because $V_{gs} = V_{in} - V_{dd} > 0$ is satisfied. The protection diode **511** is turned off. Therefore, the potential of the wiring **515** becomes V_{dd} , so that $V_{out} = V_{dd}$ is satisfied.

On the other hand, in the case of $V_{in} < V_{ss}$, the protection diode **510** is turned off. The protection diode **511** is turned on because $V_{gs} = V_{ss} - V_{in} > 0$ is satisfied. Therefore, the potential of the wiring **515** becomes V_{ss} , so that $V_{out} = V_{ss}$ is satisfied.

As described above even in the case of $V_{in} < V_{ss}$ or $V_{dd} < V_{in}$, operations can be performed in a range of $V_{ss} < V_{out} < V_{dd}$. Therefore, even in the case where V_{in} is excessive or too low, V_{out} can be prevented from being excessive or too low. Accordingly, even when the potential V_{in} is lower than the potential V_{ss} due to noise or the like, the potential of the wiring **515** does not become extremely lower than the poten-

35

tial V_{ss} . Further, the capacitor 512 and the capacitor 513 reduce pulsed noise of the input potential V_{in} and relieve a steep change in potential.

When the protection circuits are provided as described above, the potential of the wirings 515 is kept almost between the potential V_{ss} and the potential V_{dd} . Therefore, the potential of the wiring 515 can be prevented from deviating from this range greatly, and a circuit in the next stage of the protection circuit (a circuit, an input portion of which is electrically connected to V_{out}) can be protected from being damaged or deteriorating. Further, when a protection circuit is provided for an input terminal, the potentials of all the wirings to which a signal is inputted can be kept constant (here, the potential V_{ss}) when a signal is not inputted. That is, when a signal is not inputted, the protection circuit also has a function of a short-circuit ring capable of short-circuiting the wirings. Therefore, electrostatic breakdown caused by a potential difference between the wirings can be prevented. In addition, since the resistance value of the resistor 514 is sufficiently large, a decrease in the potential of a signal inputted to the wiring 515 can be prevented at the time of inputting the signal.

Note that the protection circuit used in the present invention is not limited to the structures illustrated in FIGS. 24A to 24F, and the design of the protection circuit used in the present invention can be changed as appropriate as long as it has a circuit structure having a similar function.

As the protection diode included in the protection circuit of the present invention, a diode-connected thin film transistor can be used. By the use of the thin film transistor of the present invention for the protection circuit, the area occupied by the protection circuit can be reduced, so that the frame of the display device can be narrowed and the display device can be downsized and have higher performance.

Embodiment 6

In this Embodiment, a terminal portion of the display device of the present invention will be described with reference to FIGS. 25A to 25D.

FIGS. 25A and 25B illustrate a cross-sectional view and a top view of a gate wiring terminal portion, respectively. FIG. 25A corresponds to a cross-sectional view taken along the line X1 to X2 in FIG. 25B. In FIG. 25A, a transparent conductive layer 545 stacked over a protective insulating layer 544 is a terminal electrode which functions as an input terminal. Further, in the terminal portion in FIG. 25A, a first terminal 540 which is formed with the same material as the gate wiring and a connection electrode 543 which is formed with the same material as a source wiring overlap with a gate insulating layer 542 interposed therebetween, and the first terminal 540 and the connection electrode 543 are connected (at least electrically) through a transparent conductive layer 545. A semiconductor layer 546 (an intrinsic semiconductor layer and a semiconductor layer including an impurity element imparting one conductivity type) is provided between the gate insulating layer 542 and the connection electrode 543.

FIG. 25C and FIG. 25D illustrate a cross-sectional view and a top view of a source wiring terminal portion, respectively. FIG. 25C corresponds to a cross-sectional view taken along the line Y1 to Y2 in FIG. 25D. In FIG. 25C, the transparent conductive layer 545 stacked over the protective insulating layer 544 is a terminal electrode which functions as an input terminal. Further, in the terminal portion in FIG. 25C, a second terminal 541 which is (at least electrically) connected to the source wiring and an electrode 547 which is formed with the same material as the gate wiring overlap with the gate

36

insulating layer 542 interposed therebetween. The electrode 547 is not connected to the second terminal 541 directly or electrically, and if the electrode 547 is set at a potential different from the second terminal 541, for example, floating, GND, or 0 V, capacitance for reducing noise or capacitance for preventing static electricity can be formed. The second terminal 541 is (at least electrically) connected to the transparent conductive layer 545. The semiconductor layer 546 (an intrinsic semiconductor layer and a semiconductor layer including an impurity element imparting one conductivity type) is provided between the gate insulating layer 542 and the second terminal 541.

A plurality of gate wirings, source wirings, and capacitor wirings are provided depending on the pixel density. In the terminal portion, the plurality of the first terminals at the same potential as the gate wiring, the second terminals at the same potential as the source wiring, and the third terminals at the same potential as the capacitor wiring are arranged. Each number of gate wirings, source wirings, and capacitor wirings may be determined as appropriate by a practitioner.

The terminal portion described in this Embodiment and an FPC terminal portion are connected through an anisotropic conductive paste or the like. Accordingly, signals and electric power can be supplied from outside.

Note that although FIGS. 25A to 25D show the case where the terminal portion is manufactured using a half-tone mask, the present invention is not limited to this case as described above. FIGS. 26A to 26D show the case where the terminal portion is manufactured without using a half-tone mask.

FIG. 26A and FIG. 26B illustrate a cross-sectional view and a top view of a gate wiring terminal portion, respectively, which is manufactured without using a half-tone mask. FIG. 26A corresponds to a cross-sectional view taken along the line X3 to X4 in FIG. 26B. In FIG. 26A, the transparent conductive layer 545 over the protective insulating layer 544 is a terminal electrode that functions as an input terminal. Further, in the terminal portion in FIG. 26A, the first terminal 540 which is formed with the same material as the gate wiring and the connection electrode 543 which is formed with the same material as the source wiring overlap with the gate insulating layer 542 interposed therebetween, and the first terminal 540 and the connection electrode 543 are connected (at least electrically) through the transparent conductive layer 545. The connection electrode 543 is provided on the gate insulating layer 542. FIG. 26A and FIG. 26B show a structure in which a semiconductor layer is not provided.

FIG. 26C and FIG. 26D illustrate a cross-sectional view and a top view of a source wiring terminal portion, respectively, which is manufactured without using a half-tone mask. FIG. 26C corresponds to a cross-sectional view taken along the line Y3 to Y4 in FIG. 26D. In FIG. 26C, the transparent conductive layer 545 over the protective insulating layer 544 is a terminal electrode that functions as an input terminal. Further, in the terminal portion in FIG. 26C, the second terminal 541 which is (at least electrically) connected to the source wiring and the electrode 547 which is formed with the same material as the gate wiring overlap with the gate insulating layer 542 interposed therebetween. The electrode 547 is not connected to the second terminal 541, and if the electrode 547 is set at a potential different from the second terminal 541, for example, floating, GND, or 0 V, capacitance for reducing noise or capacitance for preventing static electricity can be formed. The second terminal 541 is connected to the transparent conductive layer 545. The second terminal 541 is provided on the gate insulating layer 542. FIG. 26C and FIG. 26D show a structure in which a semiconductor layer is not

provided. That is, the terminal portions illustrated in FIGS. 26A to 26D each have a structure without a semiconductor layer.

Embodiment 7

Next, an embodiment of a display panel or a light-emitting panel, which is incorporated in the liquid crystal display device and the light-emitting display device described in the above-mentioned embodiments, will be described with reference to the accompanying drawings (cross-sectional views).

The appearance of the liquid crystal display device and the light-emitting display device which are one embodiment of the present invention is described with reference to FIGS. 27A and 27B and FIGS. 28A and 28B. FIG. 27A is a top view of a liquid crystal display panel, in which a thin film transistor 610 having a microcrystalline semiconductor layer and a liquid crystal element 613 which are formed over a first substrate 601 are sealed between the first substrate 601 and a second substrate 606 with a sealant 605. FIG. 27B is a cross-sectional view taken along the line K-L in FIG. 27A.

Each pixel of the liquid crystal display device includes a liquid crystal element. A liquid crystal element is an element that controls transmission or non-transmission of light by optical modulation action of a liquid crystal and includes a pair of electrodes and a liquid crystal. The optical modulation action of a liquid crystal is controlled by an electric field applied to the liquid crystal (including a horizontal electric field, a vertical electric field, and an oblique electric field). Note that the following can be used for a liquid crystal element and a driving mode of the liquid crystal element: a nematic liquid crystal, a cholesteric liquid crystal, a smectic liquid crystal, a discotic liquid crystal, a thermotropic liquid crystal, a lyotropic liquid crystal, a low-molecular liquid crystal, a high-molecular liquid crystal, a ferroelectric liquid crystal, an anti-ferroelectric liquid crystal, a main chain type liquid crystal, a side chain type high-molecular liquid crystal, a plasma address liquid crystal (PALC), a banana-shaped liquid crystal; a TN (Twisted Nematic) mode, an STN (Super Twisted Nematic) mode, an IPS (In-Plane-Switching) mode, an FFS (Fringe Field Switching) mode, an MVA (Multi-domain Vertical Alignment) mode, a PVA (Patterned Vertical Alignment), an ASV (Advanced Super View) mode, an ASM (Axially Symmetric aligned Micro-cell) mode, an OCB (Optical Compensated Birefringence) mode, an ECB (Electrically Controlled Birefringence) mode, an FLC (Ferroelectric Liquid Crystal) mode, an AFLC (Anti Ferroelectric Liquid Crystal) mode, a PDLC (Polymer Dispersed Liquid Crystal) mode, and a guest host mode. Note that the present invention is not limited thereto, and various kinds of liquid crystal elements can be used.

Alternatively, liquid crystal exhibiting a blue phase for which an alignment film is unnecessary may be used. A blue phase is one of liquid crystal phases, which is generated just before a cholesteric phase changes into an isotropic phase while temperature of cholesteric liquid crystal is increased. Since the blue phase is generated within an only narrow range of temperature, liquid crystal composition containing a chiral agent at greater than or equal to 5 wt % so as to improve the temperature range is used for the liquid crystal layer. The liquid crystal composition which includes liquid crystal exhibiting a blue phase and a chiral agent have such characteristics that the response time is 10 μ s to 100 μ s, which is short, the alignment process is unnecessary because the liquid crystal composition has optical isotropy, and viewing angle dependency is small.

The sealant 605 is provided so as to surround a pixel portion 602 and a scan line driver circuit 604 which are provided over the first substrate 601. The second substrate 606 is provided over the pixel portion 602 and the scan line driver circuit 604. Thus, the pixel portion 602 and the scan line driver circuit 604 are sealed together with a liquid crystal layer 608 by the first substrate 601, the sealant 605, and the second substrate 606. A signal line driver circuit 603 is provided in a region over the first substrate 601, which is surrounded by the sealant 605. Note that the signal line driver circuit 603 may be formed with thin film transistors having a polycrystalline semiconductor layer formed over a separately prepared substrate. Note that the signal line driver circuit 603 may be formed with transistors using a single-crystal semiconductor and attached to the first substrate 601.

The pixel portion 602 formed over the first substrate 601 includes a plurality of thin film transistors, and in FIG. 27B, the thin film transistor 610 included in the pixel portion 602 is exemplified. The scan line driver circuit 604 also includes a plurality of thin film transistors, and in FIG. 27B, a thin film transistor 609 included in the signal line driver circuit 603 is exemplified. The thin film transistor 610 corresponds to a thin film transistor using a microcrystalline semiconductor layer.

A pixel electrode 612 included in the liquid crystal element 613 is electrically connected to the thin film transistor 610 through a wiring 618. Further, the wiring 618 is electrically connected to a lead wiring 614. A counter electrode 617 of the liquid crystal element 613 is formed on the second substrate 906. A portion where the pixel electrode 612, the counter electrode 617, and the liquid crystal layer 608 overlap with each other corresponds to the liquid crystal element 613.

Note that as a material of each of the first substrate 601 and the second substrate 606, glass, metal (typically stainless steel), ceramics, plastics, or the like can be used. As plastics, an FRP (fiberglass-reinforced plastics) plate, a PVF (polyvinyl fluoride) film, a polyester film, an acrylic resin film, or the like can be used. Alternatively, a sheet in which aluminum foil is interposed between PVF films or polyester films may be used.

A spacer 611 is a bead spacer and is provided for controlling a distance (a cell gap) between the pixel electrode 612 and the counter electrode 617 to be constant. Note that a spacer obtained by selectively etching an insulating layer (a post spacer) may be used instead of the spacer 611 that is a bead spacer.

A variety of signals (potentials) supplied to the signal line driver circuit 603, the scan line driver circuit 604, and the pixel portion 602 are supplied from an FPC (flexible printed circuit) 607 through the lead wiring 614.

In this Embodiment, a connection terminal 616 is formed using the same conductive layer as the pixel electrode 612 included in the liquid crystal element 613. Further, the lead wiring 614 is formed using the same conductive layer as the wiring 618.

The connection terminal 616 is electrically connected to a terminal included in the FPC 607 through an anisotropic conductive layer 619.

Note that although not illustrated, the liquid crystal display device illustrated in this Embodiment includes alignment films and polarizing plates, and may further include a color filter, a light-shielding layer or the like.

An optical film such as a polarizing plate, a circular polarizing plate (including an elliptical polarizing plate), a retardation plate (a $\lambda/4$ plate, a $\lambda/2$ plate), or a color filter may be provided as appropriate over a light-emitting surface of the

light-emitting element. Further, an anti-reflection layer may be provided over a polarizing plate or a circularly polarizing plate.

FIGS. 28A and 28B illustrate an example of the light-emitting device that is an embodiment of the present invention. Note that only the portions that are different from those in FIGS. 27A and 27B are denoted by reference numerals. A light-emitting element utilizing electroluminescence is used for the light-emitting device. Light-emitting elements utilizing electroluminescence are classified according to whether a light-emitting material is an organic compound or an inorganic compound. In general, the former is referred to as organic EL elements and the latter as inorganic EL elements.

In an organic EL element, when voltage is applied to a light-emitting element, carriers (electrons and holes) are injected from a pair of electrodes into a layer containing a light-emitting organic compound, and current flows therein. Then, recombination of these carriers (the electrons and holes) allows the light-emitting organic compound to form an excited state and to emit light when the carriers in the organic compound return from the excited state to a ground state. Due to such a mechanism, such a light-emitting element is referred to as a current-excitation type light-emitting element.

Inorganic EL elements are classified into a dispersion type inorganic EL element and a thin-film type inorganic EL element depending on their element structures. A dispersion type inorganic EL element has a light-emitting layer where particles of a light-emitting material are dispersed in a binder, and its light emission mechanism is donor-acceptor recombination type light emission, which utilizes a donor level and an acceptor level. A thin-film type inorganic EL element has a structure where a light-emitting layer is sandwiched between dielectric layers, which are further sandwiched between a pair of electrodes, and its light emission mechanism is localized type light emission which utilizes inner-shell electron transition of metal ions.

Note that here, an organic EL element is used as a light-emitting element. In addition, a thin film transistor formed according to any of the methods of the above-described embodiments is used as a thin film transistor that controls driving of a light-emitting element.

First, thin film transistors 621 and 622 are formed over the substrate. An insulating layer that functions as a protective layer is formed over the thin film transistors 621 and 622. The insulating layer is preferably formed by stacking an insulating layer 623 that is formed with an inorganic material and an insulating layer 624 that is formed with an organic material, and the top surface of the insulating layer is preferably flattened using the insulating layer that is formed with an organic material. Here, as examples of an inorganic material, silicon oxide, silicon nitride, and silicon oxynitride are given. As examples of an organic material, an organic resin such as acrylic, polyimide, or polyamide, and siloxane are given.

A conductive layer is formed over the insulating layer 624 that is formed with an organic material. This conductive layer is denoted by a first conductive layer 625. The first conductive layer 625 functions as a pixel electrode. In the case where the thin film transistor of a pixel is an n-type thin film transistor, it is preferable to form a cathode as the pixel electrode. On the other hand, in the case where the thin film transistor is a p-type thin film transistor, it is preferable to form an anode as the pixel electrode. Specifically, in the case where a cathode serves as a pixel electrode, a material with low work function, such as Ca, Al, MgAg, or AlLi, may be used.

Next, a partition 626 is formed on a side face (an end portion) of the first conductive layer 625 and over the insulating layer 624 that is formed with an organic material. The

partition 626 has an opening portion and the first conductive layer 625 is exposed through the opening portion. The partition 626 is formed with an organic resin layer, an inorganic insulating layer, or organic polysiloxane. More preferably, the partition 626 is formed using a photosensitive material, and the partition 626 over the first conductive layer 625 is exposed to light so that an opening portion is formed. In this case, a sidewall of the opening portion is preferably formed as a tilted surface with continuous curvature.

Next, a light-emitting layer 627 is formed so as to be in contact with the first conductive layer 625 in the opening portion of the partition 626. The light-emitting layer 627 may be formed with either a single-layer structure or a stacked structure of a plurality of layers.

Then, a second conductive layer 628 is formed so as to cover the light-emitting layer 627. The second conductive layer 628 is referred to as a common electrode. In the case where the first conductive layer 625 is formed using a material for a cathode, the second conductive layer 628 is formed using a material for an anode. The second conductive layer 628 can be formed of a light-transmitting conductive layer using the light-transmitting conductive materials. As the second conductive layer 628, a titanium nitride layer or a titanium layer may be used. Here, indium tin oxide (ITO) is used for the second conductive layer 628. In the opening portion of the partition 626, a light-emitting element 630 is formed by overlapping of the first conductive layer 625, the light-emitting layer 627, and the second conductive layer 628. After that, it is preferable to form a protective layer over the partition 626 and the second conductive layer 627 so that oxygen, hydrogen, moisture, carbon dioxide, and the like cannot enter the light-emitting element 630. As the protective layer, a silicon nitride layer, a silicon nitride oxide layer, a DLC layer, or the like can be used. More preferably, packaging (encapsulation) is performed using a protective film (an ultraviolet curable resin film, or the like) or a cover material, which has high airtightness and causes less degassing so as to prevent exposure to air.

It is acceptable as long as the light-emitting element 630 has a transparent electrode for at least one of an anode and a cathode in order to extract light emission. There are light-emitting elements having the following structures: a top emission structure where the thin film transistors 621 and 622 and the light-emitting element 630 are formed over a substrate and light is extracted from a side opposite to the substrate; a bottom emission structure where light is extracted from the substrate side; and a dual emission structure where light is extracted from both the substrate side and the side opposite to the substrate. The light-emitting device that is an embodiment of the present invention can employ a light-emitting element with any of the above-mentioned emission structures.

In the light-emitting element 630 of the top emission structure, a light-emitting layer and an anode are sequentially stacked over the cathode. The cathode may be formed using a conductive material that has a low work function and can reflect light (for example, Ca, Al, MgAg, or AlLi). In the case where the light-emitting layer is formed using a plurality of layers, for example, an electron injection layer, an electron transport layer, a light-emitting layer, a hole transport layer, and/or a hole injection layer are stacked in that order over the cathode. Note that all these layers are not necessarily provided. The anode is formed using a light-transmitting conductive material which transmits light, and for example, a light-transmitting conductive layer of indium oxide containing tungsten oxide, indium zinc oxide containing tungsten oxide, indium oxide containing titanium oxide, indium tin oxide containing titanium oxide, indium tin oxide (hereinafter-

ter referred to as ITO), indium zinc oxide, indium tin oxide to which silicon oxide is added, or the like may be used. Light generated from the light-emitting layer is emitted to the anode side.

In the light-emitting element **630** of the bottom emission structure, a light-emitting layer and an anode are sequentially stacked over the cathode. Note that in the case where the anode has a light-transmitting property, a light-shielding layer for reflecting or shielding light may be formed so as to cover the anode. In a manner similar to the case of the top emission structure, the cathode may be a conductive layer formed using a material having a low work function, and a known material can be used therefor. Note that the thickness is set so that light can be transmitted therethrough (preferably about 5 nm to 30 nm). For example, aluminum having a thickness of 20 nm can be used as the cathode. In a manner similar to the case of the top emission structure, the light-emitting layer may be formed using either a single-layer structure or a stacked structure of a plurality of layers. Although the anode does not need to transmit light, the anode can be formed using a light-transmitting conductive material in a manner similar to that of the case of the top emission structure. The light-shielding layer can be formed using, for example, a metal layer that reflects light or a resin to which a black pigment is added. Light generated from the light-emitting layer is emitted to the cathode side.

In addition, a pixel electrode included in the light-emitting element **630** is electrically connected to a source electrode or a drain electrode of the thin film transistor **622** through a wiring. In addition, in this Embodiment, a common electrode of the light-emitting element **630** and a light-transmitting conductive material layer are electrically connected.

Note that the structure of the light-emitting element **630** is not limited to the structure shown in this Embodiment. The structure of the light-emitting element **630** can be changed as appropriate in accordance with a direction of light extracted from the light-emitting element **630**, polarity of the thin film transistor **622**, or the like.

Note that in the case where the light-emitting element **630** has the top emission structure, the second substrate that is in a direction from which light from the light-emitting element **630** is extracted should have a light-transmitting property. In this case, a substrate formed of a light-transmitting material such as a glass substrate, a plastic substrate, a polyester film, or an acrylic film is used.

As a filler **631** that is provided between the two substrate, an inert gas such as nitrogen or argon, an ultraviolet curable resin, a thermosetting resin, or the like can be used. For example, PVC (polyvinyl chloride), acrylic, polyimide, an epoxy resin, a silicone resin, PVB (polyvinyl butyral), or EVA (ethylene vinyl acetate) can be used. Here, for example, nitrogen may be used as the filler.

Note that although the example in which the thin film transistor **622** (the driving transistor) which controls driving of the light-emitting element **630** is directly connected to the light-emitting element is described in this Embodiment, a thin film transistor for controlling current may be connected between the driving thin film transistor and the light-emitting element.

Note that the light-emitting device described in this Embodiment is not limited to the structures that are illustrated in the drawings, and can be modified in various ways based on the technical idea.

This Embodiment can be combined with any of the structures described in other embodiments.

Embodiment 8

A semiconductor device including the thin film transistor according to the present invention can be applied to a variety

of electronic appliances (including game machines). As the electronic appliances, for example, there are a television device (also called a TV or a television receiver), a monitor for a computer, electronic paper, a digital camera, a digital video camera, a digital photo frame, a cellular phone (also called a mobile phone or a portable telephone device), a portable game machine, a portable information terminal, an audio playback device, and a large game machine such as a pachinko machine.

A semiconductor device including the thin film transistor according to the present invention can be applied to electronic paper. Electronic paper can be used for electronic appliances of every field for displaying information. For example, electronic paper can be used for electronic books (e-book), posters, advertisement in vehicles such as trains, or display in a variety of cards such as credit cards. Examples of such electronic appliances are illustrated in FIGS. **29A** to **29D**.

FIG. **29A** illustrates an example of an electronic book. The electronic book illustrated in FIG. **29A** includes two housings, a housing **700** and a housing **701**. The housing **700** and the housing **701** are combined with each other by a hinge **704** so that the electronic book can be opened and closed. With such a structure, operation as a paper book can be achieved.

A display portion **702** is incorporated in the housing **700** and a display portion **703** is incorporated in the housing **701**. The display portion **702** and the display portion **703** may display a series of images, or may display different images. In the structure where different images are displayed in different display portions, for example, the right display portion (the display portion **702** in FIG. **29A**) displays text and the left display portion (the display portion **703** in FIG. **29A**) displays images.

FIG. **29A** illustrates an example in which the housing **700** is provided with an operation portion and the like. For example, the housing **700** is provided with a power supply input terminal **705**, an operation key **706**, a speaker **707**, and the like. The page can be turned with the operation key **706**. Note that a keyboard, a pointing device, and the like may be provided on the same plane as the display portion of the housing. Further, a rear surface or a side surface of the housing may be provided with an external connection terminal (an earphone terminal, a USB terminal, a terminal that can be connected to a variety of cables such as a USB cable, and the like), a recording medium inserting portion, or the like. Moreover, the electronic book illustrated in FIG. **29A** may have a function of an electronic dictionary.

Further, the electronic book illustrated in FIG. **29A** may be configured to send and receive information wirelessly. Desired book data can be purchased and downloaded from an electronic book server by wireless communication.

FIG. **29B** illustrates an example of a digital photo frame. For example, a display portion **712** is incorporated in a housing **711** of the digital photo frame illustrated in FIG. **29B**. The display portion **712** can display a variety of images. For example, the display portion **712** can display data of an image taken with a digital camera or the like, so that the digital photo frame can function in a manner similar to a normal photo frame.

Note that the digital photo frame in FIG. **29B** is provided with an operation portion, an external connection terminal (a USB terminal, a terminal which can be connected to a variety of cables such as a USB cable, and the like), a recording medium inserting portion, and the like. These elements may be incorporated on the same plane as the display portion; however, they are preferably provided on the side surface or rear surface of the display portion to improve the design of the digital photo frame. For example, a memory including image

43

data taken with a digital camera is inserted into the recording medium inserting portion of the digital photo frame and the image data is imported. Then, the imported image data can be displayed in the display portion 712.

The digital photo frame in FIG. 29B may be configured to send and receive information wirelessly. In this case, desired image data can be wirelessly imported into the digital photo frame and can be displayed therein.

FIG. 29C illustrates an example of a television device. A display portion 722 is incorporated in a housing 721 of the television device in FIG. 29C. The display portion 722 can display images. Here, the housing 721 is supported by a stand 723. The display device shown in Embodiment 7 can be applied to the display portion 722.

The television device illustrated in FIG. 29C can be operated by an operation switch of the housing 721 or a separate remote controller. The channel and volume can be controlled with operation keys of the remote controller and the images displayed in the display portion 722 can be controlled. Moreover, the remote controller may have a display portion in which the information outgoing from the remote controller is displayed.

Note that the television device illustrated in FIG. 29C is provided with a receiver, a modem, and the like. With the use of the receiver, general television broadcasting can be received. Moreover, when the display device is connected to a communication network with or without wires via the modem, one-way (from a sender to a receiver) or two-way (between a sender and a receiver or between receivers information communication can be performed.

FIG. 29D illustrates an example of a cellular phone. The cellular phone in FIG. 29D includes a housing 731 in which a display portion 732 is incorporated, and further, includes an operation button 733, an operation button 737, an external connection port 734, a speaker 735, a microphone 736, and the like.

A display portion 732 of the cellular phone in FIG. 29D is a touch panel, and display contents of the display portion 732 can be operated by touching with a finger or the like. Further, making a call or text messaging can be performed by touching the display portion 732 with a finger or the like.

There are mainly three screen modes of the display portion 732. The first mode is a display mode mainly for displaying an image. The second mode is an input mode mainly for inputting information such as text. The third mode is a display-and-input mode in which two modes of the display mode and the input mode are mixed.

For example, in the case of making a call or text messaging, the display portion 732 is set to a text input mode where text input is mainly performed, and text input operation can be performed on a screen. In this case, it is preferable to display a keyboard or number buttons on almost the entire screen of the display portion 732.

When a detection device including a sensor for detecting inclination, such as a gyroscope or an acceleration sensor, is provided inside the cellular phone illustrated in FIG. 29D, display information of the display portion 732 can be automatically switched by judging the direction of the cellular phone (whether the cellular phone is placed horizontally or vertically for a landscape mode or a portrait mode).

Further, the screen modes are switched by touching the display portion 732 or operating the operation button 737 of the housing 731. Alternatively, the screen modes can be switched depending on kinds of images displayed in the display portion 732. For example, when a signal for an image displayed in the display portion is data of moving images, the

44

screen mode can be switched to the display mode. When the signal is text data, the screen mode can be switched to the input mode.

Further, in the input mode, when input by touching the display portion 732 is not performed within a specified period while a signal detected by an optical sensor in the display portion 732 is detected, the screen mode may be controlled to be switched from the input mode to the display mode.

The display portion 732 can also function as an image sensor. For example, an image of a palm print, a fingerprint, or the like is taken by touching the display portion 732 with the palm or the finger, whereby personal authentication can be performed. Further, when a backlight that emits near-infrared light or a sensing light source that emits near-infrared light is provided in the display portion, a finger vein, a palm vein, or the like can be taken.

This Embodiment can be combined with any of the structures described in other embodiments as appropriate.

This application is based on Japanese Patent Application serial no. 2008-252418 filed with Japan Patent Office on Sep. 30, 2008, the entire contents of which are hereby incorporated by reference.

What is claimed is:

1. A semiconductor device comprising:

a transistor comprising:

- a gate wiring over a first region of a substrate;
- a semiconductor layer over the gate wiring with an insulating layer interposed therebetween;
- a first wiring over and electrically connected to the semiconductor layer; and
- a second wiring over and electrically connected to the semiconductor layer;

a terminal portion comprising:

- a first metal layer over a second region of the substrate;
- a second metal layer over the first metal layer with the insulating layer interposed therebetween, the second metal layer electrically connected to the first metal layer;
- an organic insulating layer over the first metal layer, the second metal layer, and the insulating layer;
- a transparent conductive layer over the organic insulating layer, the transparent conductive layer electrically connected to the first metal layer and the second metal layer; and

- a particle over the transparent conductive layer;

a third conductive layer over the organic insulating layer, the third conductive layer electrically connected to the semiconductor layer through one of the first wiring and the second wiring; and

a liquid crystal layer over the third conductive layer, wherein the organic insulating layer is located over the gate wiring, the semiconductor layer, the first wiring and the second wiring,

wherein the first region is a different region from the second region,

wherein the first metal layer comprises a same material as the gate wiring,

wherein the second metal layer comprises a same material as one of the first wiring and the second wiring,

wherein the transparent conductive layer is in direct contact with the second metal layer through an opening of the organic insulating layer, and

wherein transmissivity of the liquid crystal layer is controlled by a horizontal electric field.

45

2. The semiconductor device according to claim 1, wherein the organic insulating layer planarizes unevenness due to a stack of the first metal layer, the insulating layer, and the second metal layer.

3. The semiconductor device according to claim 1, wherein the transparent conductive layer comprises indium tin oxide.

4. The semiconductor device according to claim 1, wherein the first metal layer comprises molybdenum, and wherein the second metal layer comprises aluminum.

5. The semiconductor device according to claim 1, wherein the transparent conductive layer is electrically connectable to a flexible printed circuit.

6. The semiconductor device according to claim 1, wherein the second metal layer is electrically connected to the first metal layer through the transparent conductive layer.

7. The semiconductor device according to claim 1, wherein the transparent conductive layer is in contact with the first metal layer.

8. The semiconductor device according to claim 1, further comprising a second semiconductor layer between the insulating layer and the second metal layer.

9. The semiconductor device according to claim 1, wherein the gate wiring and the first metal layer are in contact with the substrate.

10. The semiconductor device according to claim 1, wherein the semiconductor layer comprises a microcrystalline semiconductor.

11. The semiconductor device according to claim 1, wherein the semiconductor layer comprises silicon.

12. A module comprising:

a driver circuit comprising:

a gate wiring over a first region of a substrate;

a semiconductor layer over the gate wiring with an insulating layer interposed therebetween;

a first wiring over and electrically connected to the semiconductor layer; and

a second wiring over and electrically connected to the semiconductor layer;

a terminal portion comprising:

a first metal layer over a second region of the substrate;

a second metal layer over the first metal layer with the insulating layer interposed therebetween, the second metal layer electrically connected to the first metal layer;

an organic insulating layer over the first metal layer, the second metal layer, and the insulating layer; and

a transparent conductive layer over the organic insulating layer, the transparent conductive layer electrically connected to the first metal layer and the second metal layer; and

a particle over the transparent conductive layer;

a third conductive layer over the organic insulating layer, the third conductive layer electrically connected to the semiconductor layer through one of the first wiring and the second wiring;

a liquid crystal layer over the third conductive layer; and a flexible printed circuit electrically connected to the transparent conductive layer through an anisotropic conductive layer;

wherein the organic insulating layer is located over the gate wiring, the semiconductor layer, the first wiring and the second wiring,

wherein the first region is a different region from the second region,

wherein the first metal layer comprises a same material as the gate wiring,

46

wherein the second metal layer comprises a same material as one of the first wiring and the second wiring, wherein the transparent conductive layer is in direct contact with the second metal layer through an opening of the organic insulating layer, and wherein transmissivity of the liquid crystal layer is controlled by a horizontal electric field.

13. The module according to claim 12, wherein a pixel portion of the module comprises a first inverted staggered thin film transistor,

wherein a switch portion of the driver circuit comprises a second inverted staggered thin film transistor that comprising a microcrystalline semiconductor,

wherein a logic circuit portion of the driver circuit comprise an inverter circuit that comprises a third inverted staggered thin film transistor and a fourth inverted staggered thin film transistor, and

wherein the first to fourth inverted staggered thin film transistors have the same polarity.

14. The module according to claim 12, wherein the organic insulating layer planarizes unevenness due to a stack of the first metal layer, the insulating layer, and the second metal layer.

15. The module according to claim 12, wherein the transparent conductive layer comprises indium tin oxide.

16. The module according to claim 12, wherein the first metal layer comprises molybdenum, and wherein the second metal layer comprises aluminum.

17. The module according to claim 12, wherein the second metal layer is electrically connected to the first metal layer through the transparent conductive layer.

18. The module according to claim 12, wherein the transparent conductive layer is in contact with the first metal layer.

19. The module according to claim 12, further comprising a second semiconductor layer between the insulating layer and the second metal layer.

20. The module according to claim 12, wherein the gate wiring and the first metal layer are in contact with the substrate.

21. The module according to claim 12, wherein the semiconductor layer comprises a microcrystalline semiconductor.

22. The module according to claim 12, wherein the semiconductor layer comprises silicon.

23. A display device comprising:

a pixel portion comprising:

a gate wiring;

a semiconductor layer over the gate wiring with a first insulating layer interposed therebetween;

a first wiring over and electrically connected to the semiconductor layer;

a second wiring over and electrically connected to the semiconductor layer; and

a pixel electrode electrically connected to the semiconductor layer through one of the first wiring and the second wiring;

a terminal portion comprising:

a first metal layer;

a second metal layer over the first metal layer with the first insulating layer interposed therebetween, the second metal layer electrically connected to the first metal layer;

a second insulating layer over the first metal layer, the second metal layer, and the first insulating layer; and

a transparent conductive layer over the second insulating layer, the transparent conductive layer electrically connected to the first metal layer and the second metal layer; and

a particle over the transparent conductive layer;

47

a third conductive layer over the second insulating layer, the third conductive layer electrically connected to the semiconductor layer through one of the first wiring and the second wiring;

a liquid crystal layer over the third conductive layer; wherein the second insulating layer is located over the gate wiring, the semiconductor layer, the first wiring and the second wiring,

wherein the first metal layer comprises a same material as the gate wiring,

wherein the second metal layer comprises a same material as one of the first wiring and the second wiring,

wherein the second insulating layer comprise a first portion overlapping with the first metal layer and a second portion overlapping with the second metal layer, and

wherein a distance between a top surface of the first portion and a bottom surface of the first portion is larger than a distance between a top surface of the second portion and a bottom surface of the second portion, and

wherein transmissivity of the liquid crystal layer is controlled by a horizontal electric field.

24. The display device according to claim 23, wherein the transparent conductive layer comprises indium tin oxide.

25. The display device according to claim 24, wherein the pixel electrode comprises indium tin oxide.

48

26. The display device according to claim 23,

wherein the first metal layer comprises molybdenum, and wherein the second metal layer comprises aluminum.

27. The display device according to claim 23, wherein the second metal layer is electrically connected to the first metal layer through the transparent conductive layer.

28. The display device according to claim 23, wherein the transparent conductive layer is in contact with the first metal layer.

29. The display device according to claim 23, further comprising a second semiconductor layer between the first insulating layer and the second metal layer.

30. The display device according to claim 23, wherein the gate wiring and the first metal layer are in contact with a substrate.

31. The display device according to claim 23, wherein the semiconductor layer comprises a microcrystalline semiconductor.

32. The display device according to claim 23, wherein the transparent conductive layer is in contact with the second metal layer through an opening of the second insulating layer.

33. The display device according to claim 23, wherein the semiconductor layer comprises silicon.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 9,048,147 B2
APPLICATION NO. : 13/613811
DATED : June 2, 2015
INVENTOR(S) : Shunpei Yamazaki et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

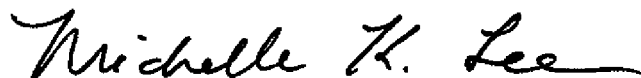
In the Specification:

Col. 34, line 12, "521" should read --521,--

Col. 43, line 30, "receivers" should read --receivers)--

Col. 46, line 60, "electrically" should read --electrically connected to--

Signed and Sealed this
Eighth Day of December, 2015

A handwritten signature in black ink, reading "Michelle K. Lee". The signature is written in a cursive, flowing style.

Michelle K. Lee
Director of the United States Patent and Trademark Office